



In the matter of

U.S. Patent Application No. 10/617,805

In the name of Tomoyoshi Yamashita, et al.

#### DECLARATION

I, Yasuo Omote, c/o YAMASHITA & ASSOCIATES of Toranomom 40th MT Building, 13-1, Toranomom 5-chome, Minato-ku, Tokyo, Japan, do solemnly and sincerely declare that I well understand the Japanese language and the English language and that the attached English translation of a certified copy of Japanese Patent Application No. 2000-380893 is a true, correct and faithful translation to the best of my knowledge and belief from the Japanese language into the English language.

Dated this 12th day of October, 2005

A handwritten signature in cursive script, appearing to read "Yasuo Omote".

Yasuo Omote

(Translator)



(Translation)

JAPAN PATENT OFFICE

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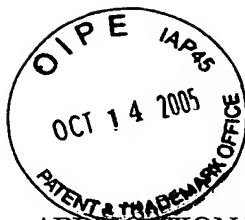
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**【Name of Object】** Specification 1

**【Name of Object】** Drawings 1

**【Name of Object】** Abstract 1

**【Proof】** Requested

**【Document Name】** SPECIFICATION

**【Title of Invention】** PLANAR LIGHT SOURCE SYSTEM AND LIGHT DEFLECTING DEVICE THEREFOR

**【Scope of Patent Claim】**

**【Claim 1】** A planar light source system comprising:

at least one primary light source of substantially point-shape;

a light guide having a light incident face on which light emitted from said primary light source is incident, guiding the incident light and having a light emission face from which the incident light is emitted; and

a light deflecting device for controlling a direction of an emission light from said light guide,

wherein said primary light source is disposed at a corner portion or an end surface of said light guide, and many substantially arc-shaped elongated prisms are formed in parallel to each other on at least one surface of said light deflecting device so as to surround said primary light source.

**【Claim 2】** A planar light source system comprising:

at least one primary light source of substantially point-shape;

a light guide having a light incident face on which light emitted from said primary light source is incident, guiding the incident light and having a light emission face from which the incident light is emitted; and

a light deflecting device for controlling a direction of an emission light from said light guide,

wherein said primary light source is disposed through an air or a transparent material in a recess portion or a through hole formed on a back surface of said light guide on the opposite side to the light emission face, and many substantially arc-shaped elongated prisms are formed in parallel to each other on at least one surface of said light deflecting device so as to surround said primary light source.

**【Claim 3】** The planar light source system as claimed in claim 1 or 2, wherein said elongated prisms are formed on at least a surface of said light deflecting device which confronts said light guide.

【Claim 4】 The planar light source system as claimed in claim 3, wherein light incident on at least one prism face of each elongated prism of the light deflecting device is totally reflected so as to be deflected substantially in a normal direction of the light emission face of the light guide.

【Claim 5】 The planar light source system as claimed in claim 3 or 4, wherein each elongated prism of said light deflecting device comprises two prism faces, one prism face being farther from said primary light source and another prism face being nearer to said primary light source, and an intersecting angle between said prism face farther from said primary light source and a reference plane of said light deflecting device is equal to 40 to 80 degrees.

【Claim 6】 The planar light source system as claimed in any one of claims 2 to 5, wherein when there are assumed plural virtual elongated prisms each having an apex angle of  $\theta$  arranged at the same arrangement pitch as an arrangement of said elongated prisms of said light deflecting device, the apex angle  $\theta$  being set so that virtual light emitted from the light emission face of the light guide in a direction of peak emission light of an angular distribution of light emitted from the light emission face of the light guide and going past an apex portion of a neighboring virtual elongated prism is incident on one prism face of each virtual elongated prism and internally totally reflected by another virtual prism face to be deflected in a normal direction of a light emission surface of said light deflecting device, the shape of each elongated prism is set to such a convex curved-surface shape relative to the shape of each virtual elongated prism that the prism face of the elongated prism has an inclination angle larger than the inclination angle of at least a part of the prism face of the virtual elongated prism relative to the light emission surface in an area which is nearer to the light emission surface of said light deflecting device than the internally total reflection position of the prism face of the virtual elongated prism.

【Claim 7】 The planar light source system as claimed in claim 1 or 2, wherein said light deflecting device has the elongated prisms formed on at least a surface on the opposite side to a surface confronting said light guide.

【Claim 8】 The planar light source system as claimed in claim 7, wherein light introduced into the light deflecting device is refracted by at least one prism face of each

elongated prism so as to be deflected substantially in a normal direction of the light emission face of the light guide.

**【Claim 9】** The planar light source system as claimed in claim 7 or 8, wherein each elongated prism of said light deflecting device comprises two prism faces, one prism face being farther from said primary light source and another face being nearer to said primary light source, and an intersecting angle between said prism face farther from said primary light source and a reference plane of said light deflecting device is equal to 35 to 55 degrees while an intersecting angle between the prism face nearer to said primary light source and the reference plane of said light deflecting device is equal to 35 to 55 degrees.

**【Claim 10】** The planar light source system as claimed in any one of claims 1 to 9, wherein said light guide contains therein a structure having a refractive index different from that of said light guide.

**【Claim 11】** The planar light source system as claimed in any one of claims 1 to 10, wherein said light guide has an uneven shape on at least one surface thereof.

**【Claim 12】** The planar light source system as claimed in claim 11, wherein an average slant angle of the uneven shape formed on the surface of said light guide is equal to 2 to 12 degrees.

**【Claim 13】** The planar light source system as claimed in claim 11 or 12, wherein the uneven shape formed on the surface of said light guide comprises many substantially arc-shaped elongated prisms formed in parallel to each other so as to surround said primary light source.

**【Claim 14】** The planar light source system as claimed in claim 13, wherein said elongated prisms are discretely arranged with a flat portion interposed between neighboring elongated prisms.

**【Claim 15】** The planar light source system as claimed in claim 14, wherein the ratio of the prism portion to the flat portion is increased as the distance from said primary light source is increased.

**【Claim 16】** The planar light source system as claimed in claim 14, wherein the ratio of the prism portion to the flat portion is varied in a circumferential direction of an arc-shape

surrounding said primary light source.

**【Claim 17】** The planar light source system as claimed in claim 14, wherein the ratio of the prism portion to the flat portion is small at a position where the intensity of light emitted from the light guide is large, while the ratio of the prism portion to the flat portion is large at a position where the intensity of light emitted from the light guide is small.

**【Claim 18】** The planar light source system as claimed in any one of claims 13 to 17, wherein resin is embedded in a part of concave portion between the adjacent elongated prisms so as to form a flat surface.

**【Claim 19】** The planar light source system as claimed in claim 11 or 12, wherein the uneven shape formed on the surface of said light guide is a roughened surface.

**【Claim 20】** The planar light source system as claimed in claim 19, wherein an average slant angle of the uneven shape formed on the surface of said light guide is increased as the distance from said primary light source is increased.

**【Claim 21】** The planar light source system as claimed in any one of claims 1 to 20, wherein said light guide has uneven grooves on the light emission face or the opposite face thereto so that the uneven grooves extend in a radial direction with said primary light source positioned substantially at the center.

**【Claim 22】** The planar light source system as claimed in claim 21, wherein the width of the uneven grooves formed on said light guide is increased as the distance from said primary light source is increased.

**【Claim 23】** The planar light source system as claimed in claim 21 or 22, wherein the uneven grooves formed on said light guide have a substantially triangular cross section.

**【Claim 24】** The planar light source system as claimed in claim 23, wherein the uneven grooves formed on said light guide comprise a slant face having an angle of 15 to 65 degrees relative to a reference plane of the light guide.

**【Claim 25】** The planar light source system as claimed in claim 23 or 24, wherein the uneven grooves formed on said light guide have the apex portion having a cross section of a curved-line shape of radius of curvature  $R$ , and the ratio ( $R/P$ ) of the radius of curvature  $R$  and the width of the grooves  $P$  is set in the range from 0.1 to 0.7.

**【Claim 26】** The planar light source system as claimed in any one of claims 1 to 25,

wherein the thickness of the light guide is reduced as the distance from said primary light source is increased.

**【Claim 27】** The planar light source system as claimed in any one of claims 1 to 26, wherein the primary light source is an LED light source.

**【Claim 28】** The planar light source system as claimed in claim 27, wherein plural LED light sources are used as said at least one primary light source.

**【Claim 29】** The planar light source system as claimed in any one of claims 1 to 26, wherein the primary light source is an LED array.

**【Claim 30】** The planar light source system as claimed in any one of claims 27 to 29, wherein the peak half-value width of the light emission pattern of the LED light source is 10 to 90 degrees in the direction perpendicular to the light emission face, and the peak half-value width is 80 to 180 degrees in the direction parallel to the light emission face.

**【Claim 31】** The planar light source system as claimed in any one of claims 1 to 30, wherein plural primary light sources are used as said at least one primary light source.

**【Claim 32】** A light deflecting device used in the planar light source system claimed in any one of claims 1 to 9.

**【Claim 33】** A method of manufacturing the planar light source system claimed in claim 22, comprising: providing a molded product having plural elongated prisms formed on the surface thereof, applying a material to the molded product in such a pattern as to be embedded in a part of concave portion between the adjacent elongated prisms, transferring a shape of the surface of the molded product onto the surface of a mold for forming the light guide, and forming the light guide with use of the mold.

#### **【Detailed Description of the Invention】**

##### **【Field of the Invention】**

The present invention relates to a planar light source system used for mobile electronic equipment such as a cellular phone, a portable information terminal or personal digital assistant (PDA), an electronic organizer, a game machine, a note-book type personal computer or the like, and a light deflecting device used therefor. Particularly, the present invention relates to a planar light source system using a substantially point-shaped light source



such as a LED light source or the like and designed to have a thin body and also provide reduced power consumption and high and uniform luminance.

**【Prior Art】**

Demands for mobile electronic equipment such as a cellular phone, a portable information terminal or personal digital assistant, an electronic organizer, a game machine, a note-book type personal computer, etc. have been recently enhanced, and a light source which is reduced in power consumption and designed to have a thin body and also provides high and uniform luminance has been required as a back light source for a liquid crystal display device for such a mobile electronic equipment. As the primary light source for the planar light source, there is often used a LED light source from the viewpoint of reduction in power consumption and miniaturization.

An under-lighting type in which plural linear light sources such as fluorescent lamps or the like are arranged in a housing or an edge-lighting type in which a linear light source is disposed at a side end surface of a planar light guide has been hitherto known as a back light source device used for a liquid crystal display device, a signboard, a traffic direction board or the like. With respect to the under-lighting type back light source, it is difficult to reduce the weight of the light source portion and also reduce the thickness of the light source portion, and also there occurs a see-through phenomenon that fluorescent lamps or the like used as a light source are seen through a display panel.

Therefore, the edge-lighting type has been more frequently used as a light and thin back light source device. Such an edge-lighting type light source device is a planar light source device as described below. That is, according to the planar light source device, a plate-shaped transparent material such as an acrylic resin plate or the like is usually used as a light guide, and a light source is disposed so as to confront the side end surface of the light guide. Light emitted from the light source is introduced into the light guide through the side end surface (light incident face) thereof, and the light thus introduced into the light guide is emitted in a planar shape from a light emission face of the light guide by using a light emission function such as a light diffusing portion formed on a front surface (light emission face) or back surface of the light guide. The light thus emitted by the light emission function is generally emitted in a slant direction to the emission face of the light guide, and thus it is general that an emission

direction controller such as a prism sheet or the like is mounted on the light guide to deflect the light in the normal direction of the light emission face of the light guide. For example, JP(A)-2-84618 has proposed a planar light source device in which a mat-finished surface is formed on at least one of the light emission face of the light guide and the back surface thereof and a prism sheet is mounted on the light emission face. JP(A)-5-72532 has proposed a back light system having a linear projection formed on the back surface of the light guide in parallel to the advancing direction of light. With use of such a configuration in the light guide, the distribution of the emitted light in the direction parallel to the linear light source is concentrated to the normal direction of the light emission face, to thereby enhance the luminance.

**【Problem to be solved by the Invention】**

Besides, a planar light source device using a LED light source is disclosed in JP(A)-9-81048 or JP(A)-9-152360. According to the disclosure of the former publication, one of the main surfaces of the light guide is set to a mat-finished surface while linear elongated prisms extending in parallel to each other are disposed on the other surface. Further, according to the disclosure of the latter publication, an LED light source is disposed at the bottom side of a light guide having an elongated prism shape on the back surface thereof, and light is incident at the bottom side of the light guide and guided to the light guide with use of a mirror. According to these planar light source devices described above, light is directed in the normal direction of the emission face of the light guide by the action of the elongated prism shape provided to the light guide. However, since the elongated prism extending straightly is formed in parallel to each other, light emitted from the LED light source in a slant direction cannot be directed in the normal direction of the light emission face of the light guide, so that only an area in front of the LED light source is bright and thus luminance unevenness occurs.

Furthermore, JP(A)-7-320514 proposes that a light source is disposed at the corner portion of a light guide and a diffusing light guide is used, and JP(A)-8-184829 discloses that both the surfaces of a light guide are roughened. However, according to these planar light sources using the diffusing light guide or the light guide having roughened surface, light is emitted in a slant direction to the light emission face, and thus the luminance is lowered in the normal direction.

Still furthermore, JP(A)-11-232918 and JP(A)-11-329039 proposes that a diffusion pattern is formed on the back surface of a light guide so that it is disposed discretely and arcuately with respect to a point light source. Since the diffusion pattern is formed arcuately, the light emitted from the point light source is incident on the arcuately formed pattern always at the same incident angle and therefore the above-mentioned luminance unevenness can be moderated. However, it is impossible for the formation of such a diffusion pattern made of circular cylinder shape or triangular prism shape as disclosed in these publications to efficiently emit light propagating through the light guide in the normal direction of the light emission face of the light guide, so that sufficient luminance cannot be achieved. In addition, when the diffusion pattern is disposed arcuately around the point light source and discretely in circumferential direction as disclosed in these publications, cost for manufacturing the light guide becomes high, and the manufacturing method is restricted so that there cannot be used a cutting method or the like by which the pattern is easily formed. According to etching method by which the discrete pattern is easily formed, shape to be formed is restricted so that it is difficult to form a triangular shape of high planarity.

Therefore, an object of the present invention is to provide a planar light source system which is suitably used as a planar light source for use in a display device for mobile electronic equipment such as a cellular phone, a portable information terminal or personal digital assistant, an electronic organizer, a game machine, a note-book type personal computer or the like, especially as a planar light source using a substantially point-shaped light source such as a LED light source or the like, and low in power consumption, small in thickness, high in luminance and excellent in luminance uniformity, and a light deflecting device used in the planar light source system.

**【Means for Solving the Problem】**

A planar light source system according to the present invention comprises:

at least one primary light source of substantially point-shape;

a light guide having a light incident face on which light emitted from the primary light source is incident, guiding the incident light and having a light emission face from which the incident light is emitted; and

a light deflecting device for controlling a direction of an emission light from the light

guide,

wherein the primary light source is disposed at a corner portion or an end surface of the light guide, and many substantially arc-shaped elongated prisms are formed in parallel to each other on at least one surface of the light deflecting device so as to surround the primary light source.

Another planar light source system according to the present invention comprises:

at least one primary light source of substantially point-shape;

a light guide having a light incident face on which light emitted from the primary light source is incident, guiding the incident light and having a light emission face from which the incident light is emitted; and

a light deflecting device for controlling a direction of an emission light from the light guide,

wherein the primary light source is disposed through an air or a transparent material in a recess portion or a through hole formed on a back surface of the light guide on the opposite side to the light emission face, and many substantially arc-shaped elongated prisms are formed in parallel to each other on at least one surface of the light deflecting device so as to surround the primary light source.

A light deflecting device according to the present invention is used in the above planar light source system.

#### **【Preferred Embodiments of the Invention】**

Preferred embodiments according to the present invention will be described hereunder in detail with reference to the accompanying drawings.

Fig. 1 shows an embodiment of a planar light source system according to the present invention. The planar light source system comprises a primary light source 1 of substantially point-shape, a light guide 2 and light deflecting device 3. The primary light source 1 is disposed at a corner portion of the light guide 2. The light deflecting device 3 is mounted on a light emission face 4 of the light guide 2. The light deflecting device 3 has arc-shaped elongated prisms 5 on at least one surface thereof. The arc-shaped elongated prisms 5 are arranged so as to surround the primary light source 1.

Light emitted from the primary light source 1 is introduced into the light guide 2, propagates through the light guide 2, and then is emitted from the light emission face 4. The light emitted from the light emission face 4 is introduced into the light deflecting device 3. A light reflecting sheet 6 is disposed on a surface of the light guide 2 on the opposite side to the light emission face 4 of the light guide 2. When both the propagation direction of light in the light guide 2 and the direction of the elongated prisms 5 formed on the light deflecting device 3 are arc-shape with the primary light source 1 positioned at the center, all the lights emitted from the point-shaped primary light source 1 are incident on the elongated prisms 5 of the light deflecting device 3 in a direction perpendicular to the direction of the elongated prisms 5. Therefore, the light can be efficiently deflected to a specific direction. If the shape of the elongated prisms are designed so that the light propagating in the direction perpendicular to the elongated prisms 5 is deflected to the normal direction of the light emission face 4 of the light guide 2, the luminance per unit power consumption is increased and simultaneously, uniformity of the luminance is also enhanced because there is not caused a phenomenon that only an area in front of the primary light source is bright.

The pattern of the elongated prisms 5 formed on the light deflecting device 3 of the present invention may be suitably set in accordance with the arrangement of the primary light source 1 as shown in Figs. 2 to 6, for example. Fig. 2 shows a case where plural primary light sources 1 are arranged at plural corner portions of the light guide 2. Fig. 3 shows a case where a primary light source 1 is disposed at one end surface of the light guide 2. Fig. 4 shows a case where plural primary light sources 1 are disposed at one end surface of the light guide 2. Fig. 5 shows a case where plural primary light sources 1 are disposed at plural end surfaces of the light guide 2.

Fig. 6 shows a case where a primary light source 1 is disposed at the center portion of the light guide 2. A recess portion 7 or a through hole for receiving the primary light source 1 is formed on the back surface of the light guide 2, and the primary light source 1 is disposed in the recess portion 7 through air, transparent material such as resin or the like.

Preferred shape of the elongated prisms 5 of the light deflecting device 3 is due to whether the elongated prisms 5 are formed on the side confronting the light emission face 4 of the light guide or on the opposite side.

First, the former case will be explained hereunder.

A set of the elongated prisms 5 comprises a prism unit formed repeatedly. Functions of each elongated prism 5 are explained with reference to Fig. 7, which is a cross-sectional view of the light deflecting device 3 along a line passing through the primary light source 1. Here, a reference plane 8 of the light deflecting device 3 is defined as a plane on the assumption that the surface on which the elongated prisms 5 of the light deflecting device 3 are formed is smooth. Major part of amount of the light emitted from the light emission face 4 of the light guide 2 has a direction which is slant relative to the light emission face 4. The shape of the elongated prism 5 is set so that such a light passes through the light deflecting device 3 and then a major part thereof has a direction substantially parallel to the normal direction of the light emission face 4 of the light guide 2. In order to deflect the light greatly, the light deflecting sheet of the present invention has a face 9 for totally reflecting the light.

When each elongated prism 5 comprises two faces, the light is incident on and refracted by a face 10 of the elongated prism 5 which is nearer to the primary light source 1, internally reflected from the face 9 of the elongated prisms 5 which are farther from the primary light source 1, and then emitted from a light emission surface 11 of the light deflecting device 3.

In case of using such a light deflecting device 3, it is supposed that the peak light of the emission light distribution of the light emitted from the light emission face 4 of the light guide 2 is inclined with respect to the light emission face 4 by 10 to 50 degrees. The intersecting angle between each prism face 9 farther from the primary light source 1 and the reference plane 8 of the light deflecting device 3 is preferably set in the range from 40 to 80 degrees, and more preferably in the range from 40 to 50 degrees. When the intersecting angle is set to a value without such a range, it becomes difficult to deflect the emission light having such a distribution to the normal direction.

The light introduced into the light guide 2 is gradually emitted from the light emission face 4. In order to make the amount of light emitted from the light guide uniform for regions of the light emission face of the light guide, the amount of light emitted from each region of the light emission face should be restricted to a certain extent. Therefore, a part of the light propagating through the light guide 2 is not emitted from the light emission face to reach the end portion of the light guide 2 and then is reflected and returned from the end surface thereof. Such a light 12 is emitted from the light guide 2 and introduced into the light deflecting device 3 so that the light 12 is incident on and refracted by the face 10 and reaches the face 9. If an angle of the face 9 relative to the light emission surface 11 greatly differs from another angle of the face 10 relative to the light emission surface 11, it is difficult to deflect the light 12 to the normal direction of the light emission face 4 of the light guide. Therefore, it is preferable to set angles of the face 9 and face 10 relative to the reference plane 8 substantially equal. For example, the difference between the above angles of the face 9 and face 10 is preferably set to 10 degrees or less, more preferably to 5 degrees or less, still more preferably 2 degrees or less. In such a manner as taking symmetry of the elongated prism into consideration, it is preferable that the angle of the face 9 farther from the primary light source 1 relative to the reference plane 8 of the light deflecting device 3 is 50 to 70 degrees, more preferably 55 to 66 degrees. Thus, it is preferable to set the shape of the elongated prism substantially symmetric with respect to right and left.

In an application field of the planar light source system for portable electronic equipment in which it is strongly required to increase luminance per power consumption, it is preferable to set the elongated prism 5 of the light deflecting device 3 to that as shown in Fig. 8, where the shape of the elongated prism is set as follows.

First, the pitch of the elongated prism arrangement is represented by  $P$  and a virtual elongated prism I is set. The intersecting angle between two prism faces I-1, I-2 of the virtual elongated prism I (that is, the apex angle of the virtual elongated prism) is represented by  $\theta$ . The angle  $\theta$  of the virtual elongated prism I is set so that the peak emission light (angle of inclination:  $\alpha$ ) of an intensity distribution of light coming from the light emission face 4 of the light guide 2 goes

past the apex portion of a neighboring virtual elongated prism on the primary light source side and is introduced into the virtual elongated prism I, where the peak emission light is refracted by the virtual prism face I-1 at a position K1 and internally reflected (preferably totally reflected) from the virtual prism face I-2 at a position K2 to be deflected in the normal direction of the light emission surface 11.

Next, on the basis of the shape of the virtual elongated prism I which is set as described above, the shape of the actual elongated prism is set to such a convex curved-surface shape that the prism face of the actual elongated prism has an inclination angle larger than the inclination angle of the prism face I-2 of the virtual elongated prism I in an area which is nearer to the light emission surface 11 than the internal reflection position K2 of the prism face I-2 of the virtual elongated prism I.

This means that the actual prism face has a larger inclination angle than that of the prism face I-2 of the virtual elongated prism I represented by the following equation (2) in any position in Z direction at which the dimension z of Fig. 2 (the distance in Z direction between the apex point of the elongated prism and the internal reflection position K2 of the virtual prism face I-2) is larger than the value represented by the following equation (1):

$$z = (P \cdot \tan \alpha \cdot \cot[\theta/2]) / (\tan \alpha + \cot[\theta/2]) \cdot \{\cot[\theta/2] + \cot \theta / (\cot[\theta/2] - \cot \theta)\} \quad \cdots (1)$$

$$\operatorname{ncos}[3\theta/2] = \sin(\alpha - [\theta/2]) \quad \cdots (2)$$

As an example of the above convex curved-surface shape may be considered a convex arc-surface shape having an apex portion and a bottom portion which are common to the virtual elongated prism (that is, the shape passing the apex portion of each virtual elongated prism and the valley portion between neighboring virtual elongated prisms) and having a radius of curvature r. Here, the value (r/P) of the radius of curvature r normalized by the pitch P is preferably set in the range from 2 to 80.

By setting the shape of the elongated prisms 5 as described above, the distribution angle (half-value width) of light emitted from the light deflecting device



3 can be reduced. The reason for this is as follows. That is, light which reaches an area nearer to the light emission surface 11 than the internal reflection position K2 of the prism face I-2 of the virtual elongated prism I is an assembly of light beams which passing through below the apex portion of a neighboring virtual elongated prism on the primary light source side at an inclination angle larger than  $\alpha$ . Accordingly, the direction of the distribution peak of the light beams is an inclination direction having an angle larger than  $\alpha$ , and the direction of the distribution peak of the internal reflection light corresponds to the direction which is inclined toward a direction along the virtual prism face of the internal reflection from the normal direction of the light emission surface 11. Such light has an action of expanding the angular distribution of the emission light from the light emission surface 11. Therefore, in order to emit light while the light amount is concentrated to a specific direction, the inclination angle of the prism face of the actual elongated prism at a position nearer to the light emission surface 11 than the internal reflection position K2 of the prism face I-2 of the virtual elongated prism I is set to be larger than the inclination angle of the corresponding virtual prism face, whereby the traveling direction of the light which is actually internally reflected in this area can be corrected to be more shifted toward the normal direction of the light emission surface 11 as compared with the reflection light from the virtual prism face.

The actual prism face corresponding to the virtual prism face I-1 is preferably designed to have the same shape as described above (that is, the shape which is symmetrical with the actual prism face corresponding to the virtual prism face I-2 with respect to the normal direction of the light emission surface 11).

In case of an asymmetrical elongated prism, the above equation on the value of  $z$  cannot be directly used. However, when the pitch of the asymmetrical elongated prisms is determined and the inclination angle of the prism face I-1 nearer to the light source is set to some value, the internal reflection position K2 and the inclination angle of the prism face I-2 can be uniquely determined so that a light beam which goes past the apex portion of a neighboring virtual prism from the light guide and is refracted and transmitted through the I-2 face at a certain emission

peak angle is totally reflected (deflected) at the position of K2 of the prism face I-2 to the normal direction, whereby a virtual asymmetrical triangle can be assumed and the prism design principle to narrow the angle of visual field can be applied in the same manner as described above.

It is possible to apply such a design to another cases as follows. When it is required that the peak emission light is emitted at a desired angle which does not correspond to the normal direction of the planar light source device to narrow the angle of visual field, irrespective of whether the elongated prism is symmetric or asymmetric, the inclination angle of the prism face I-2 and the position K2 can be uniquely determined so that a light beam which goes past the apex portion of the neighboring virtual prism and is refracted and passed through the prism face I-1 at a certain emission peak angle is directed to the desired direction, and thus the design principle to narrow the angle of visual field can be applied in the same manner as described above.

On the other hand, when the peak emission light is required to be emitted at a desired angle and the angle of visual field is required to be expanded (the width of the angular distribution of the emission light from the planar light source is increased) unlike the above case, the inclination angle of a part or the whole of the prism face nearer to the light guide than the position K2 of the prism face I-2 is set to be larger than the inclination angle of the virtual prism face, whereby the angle of visual field can be expanded, that is, the emission light distribution can be expanded.

Fig. 9 is a cross-sectional view of the light deflecting device 3 in which the elongated prisms 5 are formed on the surface on the opposite side to the light guide side along a line passing through the primary light source 1. Here, a reference plane 14 of the light deflecting device 3 is defined as a plane on the assumption that the surface on which the elongated prisms 5 of the light deflecting device 3 are formed is smooth.

In this case, the light is incident on the light incident surface 14 of the light deflecting device 3 while being refracted. The incident light reaches the prism face 15 farther from the primary light source 1, and is emitted therefrom while being refracted. When such a light deflecting device 3 is used, the action of deflecting

light is relatively weak, and thus a light diffusion sheet or prism sheet for controlling the traveling direction of light may be interposed between the light emission face 4 of the light guide 2 and the light deflecting device 3. Alternatively, another light diffusion sheet or prism sheet may be disposed on the light deflecting device 3 so as to direct the emission light in the normal direction of the light emission face 4 of the light guide 2.

The intersecting angle between the prism face 15 for mainly refracting the incident light and the reference plane 8 of the light deflecting device 3 is preferably set in the range from 35 to 55 degrees. If this angle is smaller than this range, the light deflecting action by refraction is generally insufficient. On the other hand, if this angle is larger than this range, the auxiliary peak is generally increased. On such a ground, even when the elongated prisms 5 are formed on the surface on the opposite side to the light guide side, it is preferable that the shape of each elongated prism 5 is substantially symmetrical between the right and left sides.

When each elongated prism comprises two prism faces, the difference between an intersecting angle of the prism face 14 relative to the reference plane 8 and another intersecting angle of the prism face 15 relative to the reference plane 8 is preferably set to 10 degrees or less, more preferably 5 degrees or less, and still more preferably 2 degrees or less.

In consideration of durability of a metal mold when the light deflecting device 3 is manufactured, each elongated prism 5 is preferably shaped to have a curved line in cross section at its apex portion or to be flattened at its apex portion. By using such a shape, the durability of the metal mold can be enhanced, and the manufacturing cost can be reduced. The working of the apex portion having such a shape is required to be performed so that the optical characteristic of the light deflecting device 3 is not damaged.

The light guide 2 of the present invention is not limited to a specific one, and any type of light guide 2 may be used insofar as it makes light emitted from the primary light source 1 propagate radially therethrough with the primary light source 1 positioned at the center and emits the light therefrom. For example, there

may be used a light guide in which an uneven shape is formed on at least one of the surfaces thereof, and/or a structure having a refractive index different from that of the base material thereof. The traveling direction of light emitted from the primary light source 1 and introduced into the light guide is gradually varied by such a structure while it propagates through the light guide 2, and then emitted from the light guide 2 when the angle of the traveling direction relative to the surface of the light guide 2 is increased to be more than the critical angle.

Examples of the former case are an embodiment in which arc-shaped elongated prisms 16 are formed on at least one of the surface of the light guide 2 with the primary light source 1 positioned at the center (Fig. 10), an embodiment in which radial elongated prisms 17 are formed on at least one of the surface of the light guide 2 with the primary light source 1 positioned at the center (Fig. 11), and an embodiment in which a roughened surface 18 is formed on at least one of the surface of the light guide 2 (Fig. 12). Examples of the case of the structure having a refractive index different from that of the base material are an embodiment in which fine particles of different-refractive-index are dispersed in the whole of the light guide 2 (Fig. 13), an embodiment in which a layer 19 having dispersed fine particles of different-refractive-index is provided on the surface or inside of the light guide 2 (Fig. 14), an embodiment in which different-refractive-index layers 20 are formed in arc shape with the primary light source 1 positioned at the center on the surface or inside of the light guide 2 (Fig. 15), and an embodiment in which different-refractive-index layers are formed radially with the primary light source 1 positioned at the center on the surface or inside of the light guide 2 (Fig. 16).

In the case where the arc-shaped elongated prisms 16 arranged around the primary light source 1 are formed on at least one of surfaces of the light guide 2, light propagating through the light guide 2 in the radial direction with the primary source 1 positioned at the center is emitted from the light emission face 4 obliquely. The light propagates through the light guide 2 in the radial direction without great deviation from the radial traveling direction, so that there can be provided a planar light source system of narrow visual field.

When the arc-shaped elongated prisms 16 arranged with the primary light source 1 positioned at the center are formed on at least one of surfaces of the light guide 2, the distribution in the radial direction of the arc-shaped elongated prisms 16 may be formed continuously as shown in Fig. 17 or discretely with flat portions interposed between the neighboring arc-shaped elongated prisms 16 as shown in Fig. 18-a. When the arc-shaped elongated prisms 16 are discretely formed, the amount of light 21 emitted from an arc-shaped elongated prism 16 and then incident on a neighboring arc-shaped elongated prism is reduced. By reducing the amount of light 21, disturbance of the distribution of the emission light emitted from the light guide 2 can be suppressed and therefore, amount of light deflected by the light deflecting device 3 in the normal direction of the light emission face 4 of the light guide 2 is increased to thereby make the normal luminance greater. When the arc-shaped elongated prisms 16 are discretely formed as described above, the arc-shaped elongated prisms 16 may be formed in a convex shape as shown in Fig. 18-b or in a concave shape as shown in Fig. 18-c. The arc-shaped elongated prisms 16 may be formed on the light emission face 4 of the light guide 2 or the back surface thereof.

Preferable shapes of the arc-shaped elongated prisms 16 are explained with reference to Fig. 19, which is a cross-sectional view of the elongated prisms 16 along a line passing through the primary light source 1. Here, a reference plane 22 of the light guide 2 is defined as a plane on the assumption that the surface on which the elongated prisms 16 of the light guide 2 are formed is smooth. The sectional shape of the elongated prism 16 may be a triangular shape, an arc shape, a semicircular shape, a polygonal shape or the like. Among these shapes, substantially the triangular sectional shape constituted by two prism faces of substantially planar is most preferable. When there are various angles of the surface of the light guide 2 relative to the light emission face 4, the traveling direction of the light in the light guide 2 may vary to emit a light 23 from the light guide, which causes to disturb the emitted light distribution. However, in case of the triangular sectional shape, angle of the surface of the light guide 2 relative to the light emission face 4 is constant, and therefore generation of a light 23 is reduced, whereby disturbance of

the emitted light distribution is reduced and the normal luminance is increased.

When varying the intersecting angle between the planar prism face 24 of the elongated prism and the reference plane 22 of the light guide 2, the emission angle (peak angle) of the peak emission light in the distribution of the emission light emitted from the light guide 2 and the half-value width of the emission light distribution are varied. If the intersecting angle is excessively great, the distribution becomes broad and the luminance in the normal direction of the light emission face of the light guide 2 is reduced. If the intersecting angle is excessively small, the amount of the emission light from the light guide 2 is reduced, and the luminance becomes insufficient. The intersecting angle between the prism face 24 and the reference plane 22 is preferably set in the range from 2 to 20 degrees, and more preferably in the range from 4 to 12 degrees.

In the case where the arc-shaped elongated prisms 16 are discretely formed, if the ratio  $L2/L1$  of a prism portion L2 having each arc-shaped elongated prism 16 formed thereon and a flat portion L1 formed between the neighboring arc-shaped elongated prisms 16 is varied in the circumferential direction of the arc-shaped elongated prisms 16, uniformity of luminance can be enhanced. That is, the ratio  $L2/L1$  is varied according to the distribution of light emitted from the primary light source, especially the ratio is reduced in a direction in which the intensity of light emitted from the primary light source is great while the ratio is increased in a direction in which the intensity of light emitted from the primary light source is small, thereby enhancing uniformity of the luminance.

By varying the ratio  $L2/L1$  in the radial direction of the arc-shaped elongated prisms 16, uniformity of luminance can be enhanced so that such unevenness of luminance that the luminance is low at corner portions of the light emission face 4 of the light guide 2 while the luminance is high in the neighborhood of the primary light source 1 can be moderated. The uniformity of the luminance can be enhanced by reducing the ratio  $L2/L1$  as the distance from the primary light source 1 is increased. Varying the interval at which the elongated prisms are formed, varying the depth of the prism shape of the elongated prisms and varying

both the interval and the depth may be used as a method of varying the ratio  $L2/L1$ .

The arc-shaped elongated prisms 16 may be formed continuously or discretely in the circumferential direction thereof. However, when forming the arc-shaped elongated prisms 16 discretely, it is difficult to form arc-shaped elongated prisms 16 each having an accurate shape. Therefore the elongated prisms are preferably formed continuously in the circumferential direction of the arc, because continuous shape can be easily formed accurately on the metal mold for manufacturing the light guide by cutting.

The amount of light emitted from the light guide 2 varies according to a magnitude of average slant angle of the arc-shaped elongated prisms 16 in a cross section along a line passing through the primary light source 1. When the average slant angle is small, sufficient amount of light is not emitted from the light guide 2, resulting in insufficient luminance. On the other hand, when the average slant angle is great, a large amount of light is emitted from the light guide 2 at the neighborhood of the primary light source 1, resulting in insufficient uniformity of luminance. The average slant angle is preferably 2 to 15 degrees, more preferably 3 to 10 degrees.

In the present invention, resin may be embedded in a desired pattern on the surface of the light guide having the arc-shaped elongated prisms 16 formed thereon to form embedding portions 25 on the surface to partially flatten the surface as shown in Fig. 20, whereby the uniformity of the luminance can be enhanced. The flattening rate is reduced at a portion where the luminance is required to be enhanced, and increased at a portion where the luminance is required to be reduced.

The pattern of the arc-shaped elongated prism 16 of the light guide 2 can be suitably set in accordance with the arrangement manner of the primary light source 1 as shown in Figs. 21 to 25, for example. Fig. 21 is a diagram showing a case where a plurality of primary light sources 1 are disposed at a plurality of corner portions. Fig. 22 is a diagram showing a case where a primary light source 1 is disposed at an end surface of the light guide 2. Fig. 23 shows a case where a plurality of primary light sources 1 are disposed at an end surface of the light guide 2. Fig. 24 shows a case where a plurality of primary light sources 1 are disposed at a

plurality of end surfaces of the light guide 2. Fig. 25 shows a case where a primary light source 1 is disposed at the center portion of the light guide 2. In this case, a recess portion or through hole 7 for receiving the primary light source is formed on the back surface of the light guide 2. The primary light source 1 is disposed in the recess portion 7 through air or transparent material such as resin. On the back surface of the light guide 2, many arc-shaped elongated prisms 16 are formed so as to be arranged around the recess portion 6 with the primary source 1 positioned at the center.

In case of the roughened surface 18 formed on any one of the surfaces of the light guide 2, the light emitted from the primary light source propagates in the light guide 2 arcuately with the primary light source positioned at the center, and emitted obliquely from the light emission face 4 of the light guide.

When the average slant angle of the roughened surface 18 is small, sufficient amount of light is not emitted from the light guide 2, resulting in insufficient luminance. On the other hand, when the average slant angle is great, a large amount of light is emitted from the light guide 2 at the neighborhood of the primary light source 1, resulting in insufficient uniformity of luminance. The average slant angle is preferably 2 to 15 degrees, more preferably 3 to 10 degrees. In order to improve the uniformity of luminance, it is preferable to increase the average slant angle as the distance from the primary light source is made greater to thereby control the amount of light emitted.

In a case where the roughened surface is formed on any one of surfaces of the light guide 2, the light tends to propagate with dispersion in a circumferential direction, and therefore it is preferable to form radial elongated prisms 17 with the primary light source positioned in the center on the surface of the light guide on the opposite side to the roughened surface 18.

When the radial elongated prisms 17 are formed on any one of the surfaces of the light guide 2, the light emitted from the primary light source 1 propagates in a direction of formation of the radial elongated prisms, namely radially with the primary light source 1 positioned at the center, and is emitted obliquely from the light emission face 4 of the light guide. By forming the radial elongated prisms 17, dispersion of the distribution of emitted light in the



circumferential direction of the radial elongated prisms 17 can be suppressed or reduced. The uniformity of the luminance can be enhanced by adjusting the ratio of the radial elongated prisms 17 to the flat portion.

Preferable arrangement patterns of the radial elongated prisms 17 are shown in Fig. 26. As shown in Fig. 26-a, a normal radial pattern that the interval between the adjacent elongated prisms 17 is increased as the distance from the primary light source 1 is increased may be formed. However, as shown in Fig. 26-b a radial pattern that the depth and width of the elongated prisms 17 are increased as the distance from the primary light source 1 is increased may be formed and, as shown in Fig. 26-c, a pattern that many elongated prisms 17 each having a relative short length are radially elongated may be formed, whereby the luminance at a position distant from the primary light source 1 can be enhanced.

In order to enhance the uniformity of the luminance in the circumferential direction with the primary light source 1 positioned at the center, as shown in Fig. 26-d, a pattern that the depth and width of the elongated prisms 17 are varied preferably in accordance with the light distribution of the emission light from the primary light source 1, for example, a pattern that the depth and width of the elongated prisms 17 are reduced along a direction in which the emission intensity is large while the depth and width of the elongated prisms 17 are increased along a direction in which the emission intensity is small is formed.

Occurrence of partial unevenness of luminance can be suppressed by utilizing principle that the light propagates along the radial elongated prisms 17. For example, as shown in Fig. 26-e, the elongated prisms 17 are formed only in the neighborhood of the primary light source 1 at which unevenness of luminance is liable to occur.

The pattern of the radial elongated prisms 17 of the light guide 2 may be suitably set in accordance with the arrangement manner of the primary light source as shown in Figs. 27 to 31. Fig. 27 shows a case where a plurality of primary light sources 1 are disposed at a plurality of corner portions of the light guide 2. Fig. 28 shows a case where a primary light source 1 is disposed at an end surface of the light

guide 2. Fig. 29 shows a case where a plurality of primary light sources 1 are disposed at an end surface of the light guide 2. Fig. 30 shows a case where a plurality of primary light sources 1 are disposed at a plurality of end surfaces of the light guide 2. Fig. 31 shows a case where a primary light source 1 is disposed at a center portion of the light guide 2. In this case, a recess portion or through hole 7 for receiving the primary light source is formed on the back surface of the light guide 2. The primary light source 1 is disposed in the recess portion 7 through air or transparent material such as resin.

Preferable shapes of the radial elongated prisms 17 are shown in Fig. 32. Fig. 32 is a cross-sectional view along a circular arc with the primary light source 1 positioned at the center. Here, a reference plane 22 of the light guide 2 is defined as a plane on the assumption that the surface on which the elongated prisms 17 of the light guide 2 are formed is smooth.

The sectional shape of the radial elongated prisms 17 may be a triangular shape, an arc shape, a semispherical shape, a polygonal shape or the like. Particularly, a substantially isosceles triangular shape in cross section is more preferable. That is, elongated prisms each comprising two planar faces 26 having substantially equal inclination angle relative to the reference plane 22.

In the radial elongated prisms 17 each having a triangular shape in cross section as described above, the efficiency to control the emission light distribution of the light emitted from the light emission face 4 of the light guide 2 to the direction of the radial elongated prisms 17 is varied in accordance with the intersecting angle between the face 26 of each radial elongated prism 17 and the reference plane 22 of the light guide 2 as shown in Fig. 32. The intersecting angle between the reference plane 22 of the light guide 2 and the face 26 of each radial elongated prism 17 is preferably set in the range from 15 to 65 degrees, more preferably in the range from 15 to 40 degrees, and still more preferably in the range from 20 to 25 degrees.

Each radial elongated prism 17 having a substantially triangular cross section may have a flat or curved-surface apex portion (that is, the cross section thereof has a curved-line shape). When the apex portion has a curved-line shape in

cross section, the ratio (R/P) of the radius of curvature R of the apex portion to the length of the triangular bottom side (the width of the radial elongated prism 17) P is preferably set in the range from 0.1 to 0.7. By setting R/P in the above range, functions of the radial elongated prisms 17 for controlling the emission light distribution of the light emitted from the light emission face 4 of the light guide 2 to the direction of the radial elongated prisms 17 can be efficiently achieved.

Regarding the shapes of the light guide 2, such a wedge shape that the thickness is reduced as the distance from the primary light source 1 is increased is preferable.

Substantially point-shaped light source such as a LED light source, halogen lamp or the like is preferably used as the primary light source 1 for the planar light source system of the present invention. Such a substantially point-shaped primary light source 1 may be disposed at a notch portion which is formed at a corner portion of the light guide 2 as shown in Figs. 1 and 2, or disposed at an end surface of the light guide as shown in Figs. 3 to 5, or disposed inside the light guide of the planar light source as shown in Fig. 6. Further, a monochromatic light source, a white light source containing light having wavelengths of three primary colors of red, green and blue or the like may be used as the substantially point-shaped primary light source 1.

It is preferable that a point-shaped light source having the optimum light emission pattern (emission light distribution) in accordance with its purpose or required characteristics is used as the primary light source 1. Especially, when the LED light source is used as the primary light source, angular distribution of the emission light can be controlled by shape of lens of the LED light source used. Preferred light emission patterns when the primary light source 1 is disposed at a corner portion or end surface will be described with reference to Fig. 33. In order to moderate the phenomenon that the luminance at the front side of the primary light source 1 is higher than that at the other places, it is preferable that the expansion of the light emission pattern in the direction (a) parallel to the light emission face 4 of the light guide 2 is large. The peak half-value width of the light emission pattern is

preferably equal to 120 to 180 degrees. When the primary light source 1 is disposed at the end surface of the light guide 2 as shown in Fig. 33-3, a light emission pattern having a large expansion in the direction parallel to the light emission face 4 is preferably used, and the peak half-value width is preferably equal to 140 to 180 degrees. Further, when the primary light source 1 is disposed at the corner portion of the light guide 2 as shown in Figs. 33-1 and 33-2, it is preferable that the expansion angle of the incident light is substantially coincident with the expansion of the plane of the light guide 2. Therefore, when the angle of the corner of the light guide 2 on which light is incident is equal to 90 degrees, it is preferable that the peak half-value width of the light emission pattern of the primary light source 1 is equal to about 60 to 120 degrees. When the angle of the corner is equal to 45 degrees, it is preferable that the peak half-value width of the light emission pattern of the primary light source 1 is equal to about 20 to 70 degrees.

Further, with respect to the light emission pattern in the direction (b) perpendicular to the light emission face 4 of the light guide 2, if the light emission pattern is excessively wide, the light is liable to be emitted in the neighborhood of the primary light source 1, and there is a tendency to reduce the uniformity of luminance. In addition, if the primary light source 1 is disposed apart from the light guide 2, there is a tendency to reduce a ratio of the light introduced into the light guide 2. On the other hand, if the light emission pattern is excessively narrow, the amount of light reciprocating in the light guide 2 is increased to generate leakage of light at the ends of the light guide 2, and thus there is a tendency to reduce the luminance. It is preferable that the peak half-value width of the light emission pattern is equal to 10 to 90 degrees.

In order to dispose the primary light source 1, it is preferable that a notch portion 27 is formed on the end surface of the light guide 2. As mentioned in the above, it is preferable that the expansion angle of the incident light in the light guide 2 in the direction parallel to the light emission face 4 of the light guide 2 is as wide as possible in the expansion of the plane of the light guide 2. Therefore, it is preferable that an arc-shaped notch portion 27 is formed on the surface at which the

primary light source 1 is disposed so that the primary light source 1 is located at the center of the arc-shaped notch portion 27. Further, the notch portion 27 may be designed to have an aspheric surface in order to adjust the luminance distribution in the light emission face 4 of the light guide 2.

Materials having high optical transparency such as glass, synthetic resin or the like may be used as the material constituting the light guide 2 or the light deflecting device 3. For example, acrylic resin, polycarbonate resin, vinyl chloride resin, polyolefin resin, polystyrene, copolymer of methyl methacrylate (MMA) and styrene (St) or the like may be used. Such synthetic resin as described above may be molded into a plate shape by using a normal molding method such as extrusion molding, injection molding or the like to manufacture the light guide 2 and the light deflecting device 3. Particularly, methacrylic resin such as polymethyl methacrylate (PMMA) is excellent in optical transparency, heat resistance, mechanical characteristic and molding workability, and suitably applied as the material for the light guiding material. Such methacrylic resin contains methyl methacrylate as a main component, and preferably contains methyl methacrylate of 80 wt% or more. The light guide 2 may contain light diffusing agent or fine particles.

In the present invention, ultraviolet curable resin composition may be used to provide the surface shape such as a prism shape or the like to the light guide 2 and the light deflecting device 3. As a ultraviolet curable resin composition may be used a composition mainly containing a polymerizable compound which contains acryloyl groups or methacryloyl groups in molecules, ultraviolet sensitive radical polymerization initiator, ultraviolet absorbent, etc. A compound such as photopolymerizable oligomer, multifunctional (meth)acrylate, monofunctional (meth)acrylate or the like may be used as the polymerizable compound having (meth)acryloyl groups in molecules. As the polymerizable oligomer may be used urethane poly(meth)acrylate oligomer achieved by reacting polyisocyanate having two or more isocyanate groups in a molecule with a compound having a hydroxyl group and a (meth)acryloyl group in a molecule, epoxy poly(meth)acrylate oligomer

achieved by reacting an epoxy compound having two or more epoxy groups in a molecule with a carboxyl group and a (meth)acryloyl group in a molecule, or the like.

Specifically, there may be representatively used urethane poly(meth)acrylate oligomer achieved by reacting a diisocyanate compound such as isophorone diisocyanate, tetramethyl xylylene diisocyanate, xylylene diisocyanate, tolylene diisocyanate or the like with a hydroxyl group-containing (meth)acrylate compound such as hydroxyethyl (meth)acrylate, hydroxypropyl (meth)acrylate, tetramethylol methane tri(meth)acrylate, glycerin di(meth)acrylate or the like, epoxy poly(meth)acrylate oligomer achieved by reacting bisphenol A diglycidyl ether, bisphenol F diglycidyl ether, bisphenol S diglycidyl ether, tetrabromo bisphenol A diglycidyl ether or the like with (meth)acrylic acid, or the like.

As the multifunctional (meth)acrylate compound may be used ethylene glycol di(meth)acrylate, diethylene glycol di(meth)acrylate, triethylene glycol di(meth)acrylate, polyethylene glycol di(meth)acrylate, tripropylene glycol di(meth)acrylate, polypropylene glycol di(meth)acrylate, polybutylene glycol di(meth)acrylate, 1,3-butylene glycol di(meth)acrylate, 1,6-hexanediol di(meth)acrylate, neopentyl glycol di(meth)acrylate, 2,2-bis[4-(meth)acryloyloxyphenyl]-propane, 2,2-bis[4-(meth)acryloyloxyethoxyphenyl]-propane, 2,2-bis[4-(meth)acryloyloxydiethoxyphenyl]-propane, 2,2-bis[4-(meth)acryloyloxypentaethoxyphenyl]-propane, 2,2-bis[4-(meth)acryloyloxyethoxy-3-phenylphenyl]-propane, bis[4-(meth)acryloylthiophenyl]sulfide, bis[4-(meth)acryloyloxyphenyl]-sulfone, bis[4-(meth)acryloyloxyethoxyphenyl]-sulfone, bis[4-(meth)acryloyloxydiethoxyphenyl]-sulfone, bis[4-(meth)acryloyloxypentaethoxyphenyl]-sulfone, bis[4-(meth)acryloyloxyethoxy-3-phenylphenyl]-sulfone, bis[4-(meth)acryloyloxyethoxy-3,5-dimethylphenyl]-sulfone, bis[4-(meth)acryloyloxyphenyl]-sulfide, bis[4-(meth)acryloyloxyethoxyphenyl]-sulfide, bis[4-(meth)acryloyloxypentaethoxyphenyl]-sulfide, bis[4-(meth)acryloyloxyethoxy-3-phenylphenyl]-sulfide, bis[4-(meth)acryloyloxyethoxy-3,5-dimethylphenyl]-sulfide, 2,2-bis[4-(meth)acryloyloxyethoxy-3,5-dibromophenyl]propane, trimethylol propane tri(meth)acrylate, tetramethylol

methane tri(meth)acrylate, tetramethylol methane tetra(meth)acrylate, dipentaerythritol hexa(meth)acrylate or the like.

As the monofunctional (meth)acrylate compound may be used phenyl(meth)acrylate, benzyl(meth)acrylate, phenylethyl(meth)acrylate, phenoxyethyl(meth)acrylate, paracumylphenol ethyleneoxide-denatured (meth)acrylate, isobornyl (meth)acrylate, cyclohexyl(meth)acrylate, dicyclopentenyl(meth)acrylate, dicyclopentanyl(meth)acrylate, tetrahydrofuryl(meth)acrylate, methyl(meth)acrylate, ethyl(meth)acrylate, propyl(meth)acrylate, n-butyl(meth)acrylate, i-butyl(meth)acrylate, t-butyl(meth)acrylate, penthyl(meth)acrylate, 2-ethylhexyl(meth)acrylate, n-hexyl(meth)acrylate, 2-hydroxyethyl(meth)acrylate, 2-hydroxypropyl(meth)acrylate, 2-hydroxybutyl(meth)acrylate, 4-hydroxybutyl(meth)acrylate, tetrahydrofurfuryl(meth)acrylate, phosphoethyl(meth)acrylate or the like. In the present invention, each of the above compounds may be used alone or a mixture of the two or more kinds of the above compounds may be used.

The ultraviolet sensitive radical polymerization initiator is a component for generating radicals in response to ultraviolet rays and initiates polymerization of the polymerizable compound as described above. It is preferable that the ultraviolet sensitive radical polymerization initiator has an absorption area in a wavelength area of 360 to 400nm and substantially has no absorption area in a wavelength area of 400nm or more. This is because the ultraviolet sensitive radical initiator has an absorption area in the wavelength range of 360 to 400nm and thus it absorbs ultraviolet rays which are not absorbed by the ultraviolet absorbent, thereby efficiently generating radicals. In addition, since it substantially has no absorption area in the wavelength range of 400nm or more, a lens portion having no color can be formed. The substantial no absorption in the wavelength range above 400nm means that the absorption caused by the ultraviolet sensitive radical polymerization initiator in the wavelength range of 400nm or more is equal to 1% or less in the actual using concentration of the ultraviolet sensitive radical polymerization initiator and the thickness of a light leakage modulator. The blend

amount of the ultraviolet sensitive radical polymerization initiator is preferably set in the range from 0.01 to 5 parts by weight with respect to the above polymerizable compound of 100 parts by weight, and more preferably in the range from 0.1 to 3 parts by weight. If the blend amount of the ultraviolet sensitive radical polymerization initiator is less than 0.01 parts by weight, the hardening of the polymerizable compound is likely to be delayed. On the other hand, if the blend amount exceeds 5 parts by weight, the lens portion is likely to be colored.

As specific examples of the ultraviolet sensitive radical polymerization initiator may be used 3,3-dimethyl-4-methoxy-benzophenone, benzyldimethyl ketal, isoamyl p-dimethylaminobenzoate, ethyl p-dimethylaminobenzoate, benzophenone, p-methoxybenzophenone, 2,2-diethoxyacetophenon, 2,2-dimethoxy-1,2-diphenylethane-1-one, 1-hydroxycyclohexylphenylketone, methylphenylglyoxylate, ethylphenylglyoxlate, 2-hydroxy-2-methyl-1-phenylpropane-1-one, 2-methyl-1-[4-(methylthio)phenyl]-2-morpholinopropanone-1, 2,4,6-trimethylbenzoyldiphenyl phosphine oxide, or the like. These materials may be used alone, or two or more kinds of materials may be blended with each other.

In the present invention, among these materials, methylphenylglyoxylate, 2-hydroxy-2-methyl-1-phenylpropane-1-one, 1-hydroxycyclohexylphenylketone, 2,2-dimethoxy-1,2-diphenylethane-1-one, benzyldimethylketal, 2,4,6-trimethylbenzoyldiphenyl phosphine oxide are particularly preferable from the viewpoint of hardening.

The ultraviolet absorbent used in the present invention is a component for absorbing ultraviolet rays incident as external light to suppress deterioration of the light guide layer due to the ultraviolet rays and keep the adhesion thereto for a long term. Further, the ultraviolet curable composition of the present invention may contain various additives such as oxidation inhibitor, yellowing inhibitor, blueing agent, pigment, settlement inhibitor, antifoamer, antistatic agent, antiblooming agent, etc. as occasion demands.

The above ultraviolet curable resin composition is suitable for manufacturing a fine-patterned optical sheet to be applied to a surface of a transparent



base material of film, sheet or plate.

The light deflecting device 3 of the present invention may comprise the transparent base material and a ultraviolet curable resin obtained by curing the above ultraviolet curable resin composition on at least one surface of the transparent base material. Transparent base material is not limited to specific ones, and any material may be used insofar as the ultraviolet rays can be transmitted through the material. For example, it may be a flexible glass plate or the like, however, it may be a transparent synthetic resin film, sheet or plate of acrylic resin, polycarbonate resin, vinyl chloride resin, polymethacrylimide resin, polyester resin or the like.

As the resin for forming the pattern shown in Fig. 20, there can be used a ultraviolet curable resin containing such a thickener as used in printing ink.

The light deflecting device 3 and the light guide 2 may be manufactured by a molding method. The mold is achieved by forming an uneven shape such as an elongated prism pattern or the like on a metal plate or the like by cutting, etching, electric discharge machining, laser beam machining or the like. Particularly, the cutting method is preferable because it can achieve an accurate shape in short time. The uneven shape formed on the light deflecting device 3 and the light guide 2 according to the present invention can be easily formed by cutting a surface of the mold and therefore, the planar light source device can be achieved with a reduced cost. Further, when a mold having a roughened surface is manufactured, etching, blast finishing or the like is used.

The light guide 2 and the light deflecting device 3 are manufactured by an extrusion molding method, a press molding method, a method using the ultraviolet curable resin composition or the like with use of the above mold. The injection molding method is preferably used for manufacturing the light guide 2, and the injection molding method or the method using the ultraviolet curable resin is preferably used for manufacturing the light deflecting device 3.

Further, in order to form elongated prisms which are flattened in a pattern as shown in Fig. 20, a ultraviolet curable composition is printed onto a molded product having elongated prisms formed on the surface thereof so as to be embedded

in a part of concave portion between the adjacent elongated prisms in a desired pattern. Thereafter, the ultraviolet curable resin composition is cured by irradiating ultraviolet rays, to thereby transfer the surface shape of the molded product by electroforming to achieve a mold for forming the light guide.

#### **【Examples】**

Next, the present invention will be described more specifically by the following Examples.

#### **[EXAMPLE 1]**

##### **Formation of Light Guide**

Arc-shaped elongated prisms were formed on a metal plate by cutting. Injection molding was carried out by using the metal plate as a mold to achieve a rectangular light guide of 40mm in long side length and 30mm in short side length and 0.8mm in thickness. Polymethylmethacrylate was used as material of the light guide. The light guide thus achieved had a pattern shown in Fig. 10 and a cross section shown in Fig. 18-a, where the cross section had a shape of isosceles triangle and a pitch of  $30\ \mu\text{m}$ . The intersecting angle between the slant face of the isosceles triangle and the reference plane of the light guide was 10 degrees, and the ratio  $L2/L1$  of the prism portion and the flat portion was 1.0.

##### **Formation of Light Deflecting Device**

Arc-shaped elongated prisms were formed on a metal plate by cutting. Molding with ultraviolet curable resin composition of refractive index of 1.528 was carried out on a surface of polyester film (refractive index of 1.600) of  $188\ \mu\text{m}$  in thickness by using the metal plate as a mold to achieve a rectangular light deflecting device of 40mm in long side length and 30mm in short side length. A high-pressure mercury lamp was used as a ultraviolet light source. The elongated prisms thus formed had a pattern shown in Fig. 1 and a cross section shown in Fig. 7, where the cross section had a shape of isosceles triangle and a pitch of  $50\ \mu\text{m}$ . The intersecting angle between the slant face of the isosceles triangle and the reference plane of the prism was 60 degrees.

##### **Formation of Planar Light Source System**

The light guide was disposed on a light diffusion reflection film so that the elongated prisms faced the light diffusion reflection film. The light deflecting device was mounted on a surface of the light guide on the opposite side to the surface on which the light diffusion reflection film was disposed, so that the elongated prisms faced the light guide. As the primary light source, there was used a LED light source in which the peak half-value width in the parallel direction to the light emission face of the light guide was equal to 140 degrees and the peak half-value width in the perpendicular direction was equal to 80 degrees. The LED light source was mounted at the corner portion of the light guide to thereby achieve a planar light source system.

#### Estimation

Luminance characteristics were estimated with use of a luminance colorimeter (BM-7 manufactured by Topcon Corporation) at the detection angle of 1 degree.

When the emission light luminance distribution (angular distribution of the emission light) of the planar light source system thus achieved was measured, the angular half-value width (the expansion angle of the distribution when the luminance value was equal to a half of that of the peak emission light) was equal to 20 degrees in the radial direction of the arc shape with the light source positioned at the center and equal to 10 degrees in the circumferential direction thereof. The ratio of minimum luminance/maximum luminance within a light emission surface was 70 % which was excellent. Appearance of the planar light source system was excellent.

#### [EXAMPLE 2]

#### Formation of Light Guide

Radial elongated prisms were formed on a metal plate by cutting. A blast treatment was carried out on another metal plate to achieve a roughened surface. Injection molding was carried out by using the above two metal plates as molds to achieve a rectangular light guide of 40mm in long side length and 30mm in short side length and 0.8mm in thickness. Polymethylmethacrylate was used as material of the light guide. The light guide thus achieved had on one surface thereof a pattern

shown in Fig. 26-b and a cross section shown in Fig. 32, where the cross section had a shape of isosceles triangle and a pitch of  $30\mu\text{m}$ . The intersecting angle between the slant face of the isosceles triangle and the reference plane of the light guide was 25 degrees. The average slant angle of the other surface, i.e. roughened surface, of the light guide was 2 degrees.

The average slant angle  $\theta_a$  can be obtained by measuring surface shapes with use of a surface roughness tester, obtaining a slant function  $f(x)$  with a coordinate of a measuring direction set as  $x$ , and executing a calculation with the following equations (3) and (4), in accordance with ISO 428/1-1987. Here,  $L$  is a measured length, and  $\Delta a$  is a tangent of the average slant angle  $\theta_a$ .

$$\Delta a = (1/L) \int_0^L |(d/dx)f(x)|dx \quad \dots (3)$$

$$\theta_a = \tan^{-1}(\Delta a) \quad \dots (4)$$

#### Formation of Light Deflecting Device and Planar Light Source System

The same processes as in Example 1 were carried out.

#### Estimation

When the emission light luminance distribution (angular distribution of the emission light) of the planar light source system thus achieved was measured, the angular half-value width (the expansion angle of the distribution when the luminance value was equal to a half of that of the peak emission light) was equal to 22 degrees in the radial direction of the arc shape with the light source positioned at the center and equal to 18 degrees in the circumferential direction thereof. The ratio of minimum luminance/maximum luminance within a light emission surface was 75 % which was excellent. Appearance of the planar light source system was excellent.

[EXAMPLE 3]

A planar light source system was achieved in the same manner as Example 1 except that the ratio  $L2/L1$  of the flat portion and the elongated prism portion was set to 2.0 in the neighborhood of the primary light source, to 0.5 at a position farthest from the primary light source, and to a value gradually varying therebetween. The ratio of minimum luminance/maximum luminance within a light emission surface was 85 % which was excellent. Appearance of the planar light source

system was excellent.

**[EXAMPLE 4]**

A planar light source system was achieved in the same manner as Example 1 except that a prism sheet having narrow angle of visual field of Fig. 8 was used as the light deflecting device. When the emission light luminance distribution (angular distribution of the emission light) of the planar light source system thus achieved was measured, the angular half-value width (the expansion angle of the distribution when the luminance value was equal to a half of that of the peak emission light) was equal to 18 degrees in the radial direction of the arc shape with the light source positioned at the center and equal to 10 degrees in the circumferential direction thereof.

**【Effect of the Invention】**

According to the present invention, there can be provided a planar light source system which is low in power consumption, small in thickness, high in luminance and excellent in uniformity of luminance. Therefore, the planar light source system of the present invention is suitable for use in mobile electronic equipment such as a cellular phone, a portable information terminal or personal digital assistant, an electronic organizer, a game machine, a note-book type personal computer or the like, especially as a planar light source system using a substantially point-shaped light source such as an LED light source or the like.

**【Brief Description of the Drawings】**

**【Fig. 1】**

A diagram showing the basic construction of a planar light source system according to the present invention.

**【Fig. 2】**

A diagram showing an embodiment of a pattern of elongated prisms of a light deflecting device according to the present invention, wherein plural primary light sources are disposed at plural corner portions of the light guide.

**【Fig. 3】**

A diagram showing an embodiment of a pattern of elongated prisms of a light deflecting device according to the present invention, wherein a primary light source is disposed

at an end surface of the light guide.

**【Fig. 4】**

A diagram showing an embodiment of a pattern of elongated prisms of a light deflecting device according to the present invention, wherein plural primary light sources are disposed at an end surface of the light guide.

**【Fig. 5】**

A diagram showing an embodiment of a pattern of elongated prisms of a light deflecting device according to the present invention, wherein plural primary light sources are disposed at plural end surfaces of the light guide.

**【Fig. 6】**

Diagrams showing an embodiment of a pattern of elongated prisms of a light deflecting device according to the present invention, wherein a primary light source is disposed at the center portion of the planar light source device.

**【Fig. 7】**

A diagram showing the shape of a prism unit of an embodiment of a light deflecting device according to the present invention, wherein the elongated prisms are formed on a surface on the side of the light guide.

**【Fig. 8】**

A diagram showing the shape of a prism unit of an embodiment of a light deflecting device according to the present invention, wherein the elongated prisms are formed on a surface on the side of the light guide so as to be suitable for obtaining a narrow distribution.

**【Fig. 9】**

A diagram showing the shape of a prism unit of an embodiment of a light deflecting device according to the present invention, wherein the elongated prisms are formed on a surface on the opposite side to the light guide.

**【Fig. 10】**

A diagram showing the surface shape of an embodiment of a light guide according to the present invention, wherein arc-shaped elongated prisms are formed on the surface.

**【Fig. 11】**

A diagram showing the surface shape of an embodiment of a light guide according to

the present invention, wherein radial elongated prisms are formed on the surface.

【Fig. 12】

A diagram showing the surface shape of an embodiment of a light guide according to the present invention, wherein roughened surface are formed.

【Fig. 13】

A diagram showing an embodiment of a light guide according to the present invention, wherein fine particles having refractive index different from that of the base material are dispersed therein.

【Fig. 14】

A diagram showing an embodiment of a light guide according to the present invention, wherein a layer containing fine particles having refractive index different from that of the base material is formed.

【Fig. 15】

A diagram showing an embodiment of a light guide according to the present invention, wherein a layer having refractive index different from that of the base material is formed in arc shape.

【Fig. 16】

A diagram showing an embodiment of a light guide according to the present invention, wherein a layer having refractive index different from that of the base material is formed radially.

【Fig. 17】

A diagram showing a cross section taken along a radial direction of a light guide according to the present invention which has arc-shaped elongated prisms formed thereon.

【Fig. 18】

Diagrams each showing a cross section taken along a radial direction of a light guide according to the present invention which has arc-shaped elongated prisms formed thereon.

【Fig. 19】

Diagrams each showing the shape of a prism unit of a light guide according to the present invention which has arc-shaped elongated prisms formed thereon.

【Fig. 20】

Diagrams showing an embodiment of a pattern of arc-shaped elongated prisms of a light guide according to the present invention;

**【Fig. 21】**

A diagram showing an embodiment of a pattern of arc-shaped elongated prisms of a light guide according to the present invention, wherein plural primary light sources are disposed at plural corner portions of the light guide.

**【Fig. 22】**

A diagram showing an embodiment of a pattern of arc-shaped elongated prisms of a light guide according to the present invention, wherein a primary light source is disposed at an end surface of the light guide.

**【Fig. 23】**

A diagram showing an embodiment of a pattern of arc-shaped elongated prisms of a light guide according to the present invention, wherein plural primary light sources are disposed at an end surface of the light guide.

**【Fig. 24】**

A diagram showing an embodiment of a pattern of arc-shaped elongated prisms of a light guide according to the present invention, wherein plural primary light sources are disposed at plural end surfaces of the light guide.

**【Fig. 25】**

A diagram showing an embodiment of a pattern of arc-shaped elongated prisms of a light guide according to the present invention, wherein a primary light source is disposed at the center portion of the planar light source device.

**【Fig. 26】**

Diagrams each showing an embodiment of a light guide according to the present invention which has radial elongated prisms formed thereon.

**【Fig. 27】**

A diagram showing an embodiment of a pattern of radial elongated prisms of a light guide according to the present invention, wherein plural primary light sources are disposed at plural corner portions of the light guide.

**【Fig. 28】**



A diagram showing an embodiment of a pattern of radial elongated prisms of a light guide according to the present invention, wherein a primary light source is disposed at an end surface of the light guide.

**【Fig. 29】**

A diagram showing an embodiment of a pattern of radial elongated prisms of a light guide according to the present invention, wherein plural primary light sources are disposed at an end surface of the light guide.

**【Fig. 30】**

A diagram showing an embodiment of a pattern of radial elongated prisms of a light guide according to the present invention, wherein plural primary light sources are disposed at plural end surfaces of the light guide.

**【Fig. 31】**

A diagram showing an embodiment of a pattern of radial elongated prisms of a light guide according to the present invention, wherein a primary light source is disposed at the center portion of the planar light source device.

**【Fig. 32】**

A diagram showing the shape of a prism unit of a light guide according to the present invention which has radial elongated prisms formed thereon.

**【Fig. 33】**

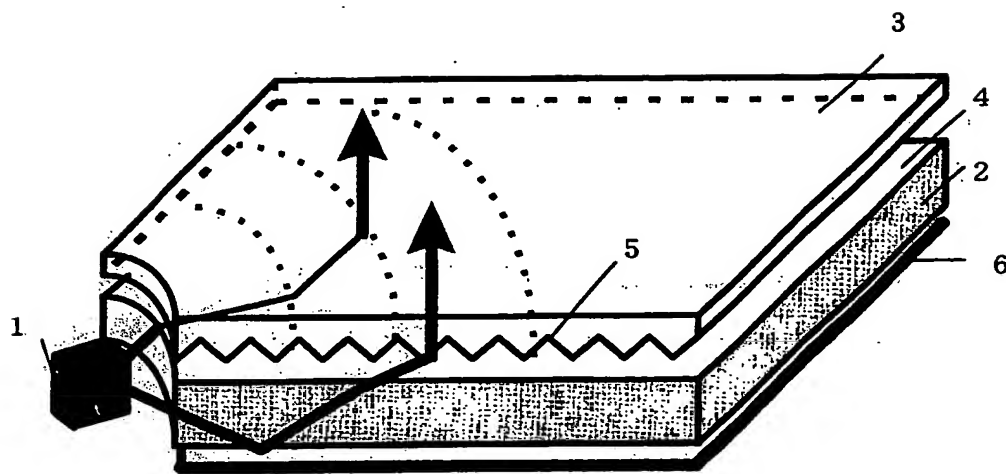
Diagrams each showing a light emission pattern of a primary light source.

**【Explanation of Reference Numerals】**

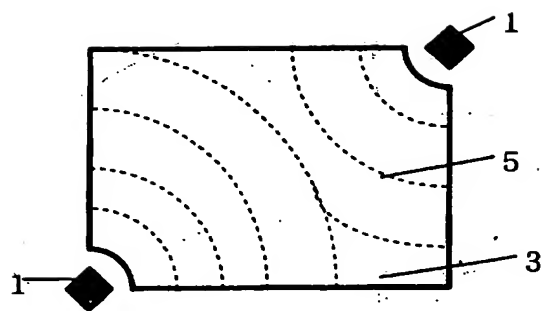
- 1 Primary light source
- 2 Light guide
- 3 Light deflecting device
- 4 Light emission face of light guide
- 5 Elongated prism of light deflecting device
- 6 Light reflecting sheet
- 7 Recess portion or through hole for receiving primary light source
- 8 Reference plane of light deflecting device
- 9 Face of prism unit farther from primary light source

- 10 Face of prism unit nearer to primary light source
- 11 Light emission surface of light deflecting device
- 12 Light reflected from end portion of light guide
- 13 Reference plane of light deflecting device
- 14 Light incident surface of light deflecting device
- 15 Face of prism unit farther from primary light source
- 16 Arc-shaped elongated prism
- 17 Radial elongated prism
- 18 Roughened surface
- 19 Layer containing dispersed fine particles having different refractive index
- 20 Layer having different refractive index
- 21 Light incident on neighboring prism unit
- 22 Reference plane of light guide
- 23 Light disturbing light emission distribution
- 24 Face of prism unit
- 25 Embedded portion formed in pattern
- 26 Face of prism unit
- 27 Notch portion

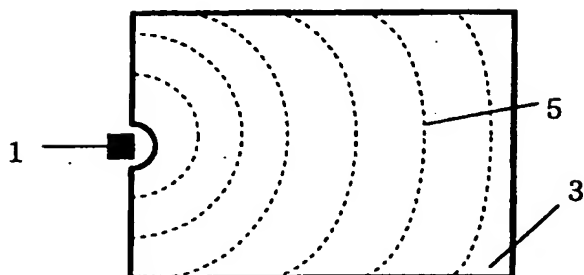
[Fig. 1]



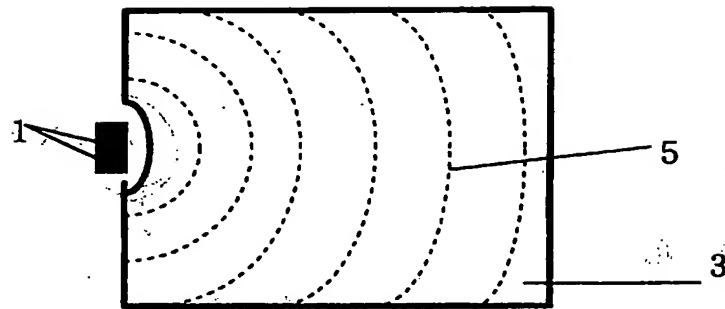
[Fig. 2]



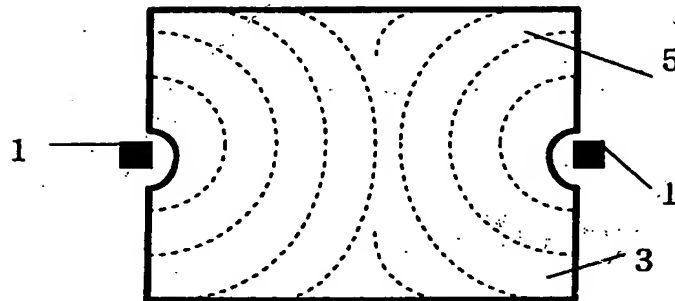
[Fig. 3]



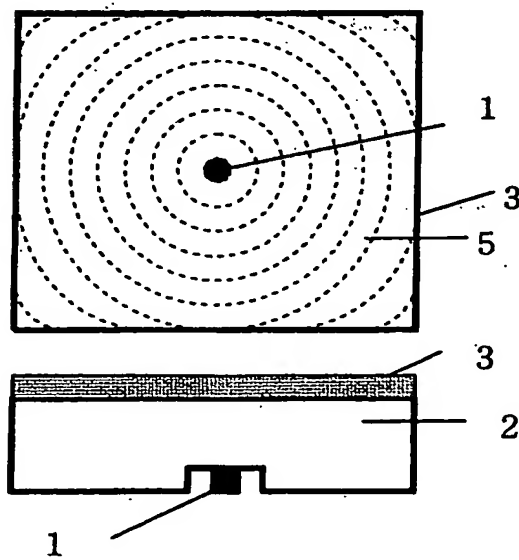
【Fig. 4】



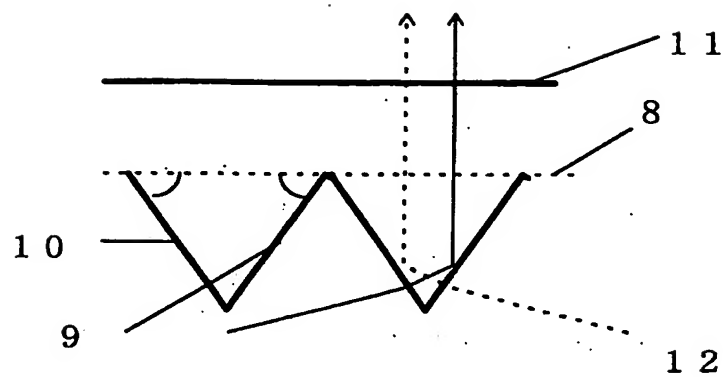
【Fig. 5】



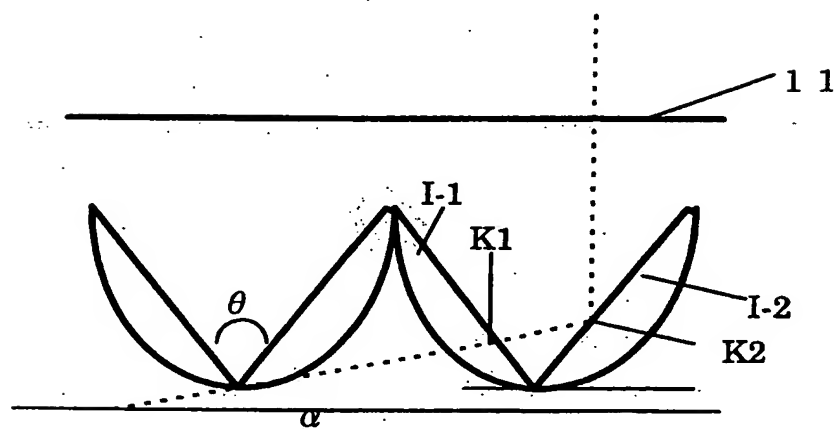
【Fig. 6】



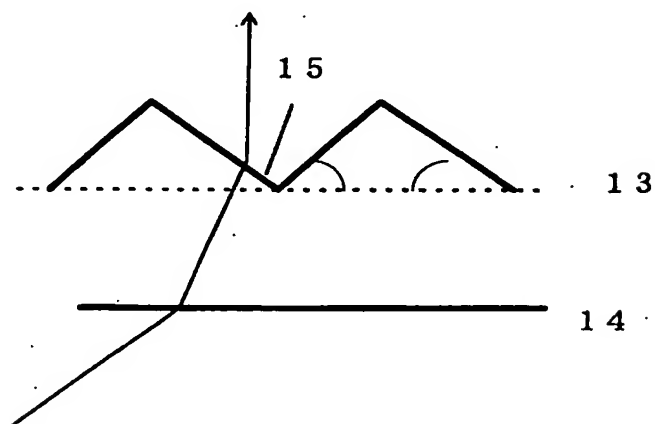
【Fig. 7】



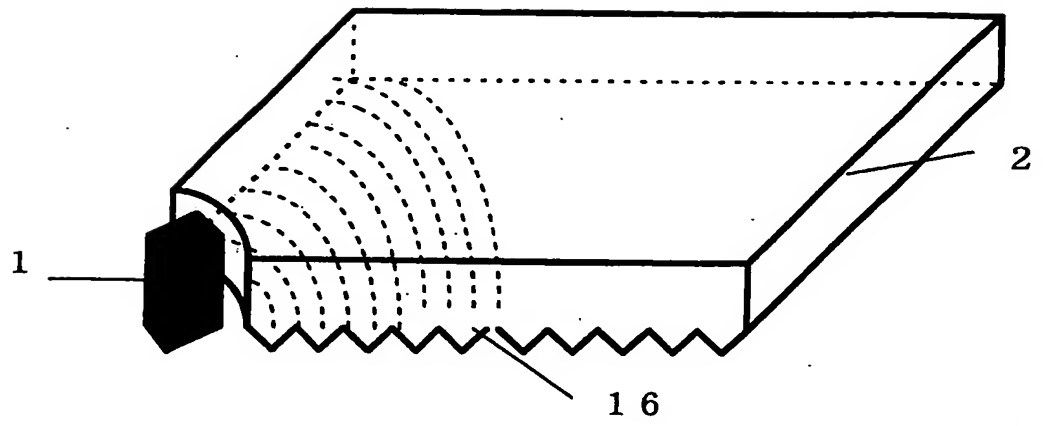
【Fig. 8】



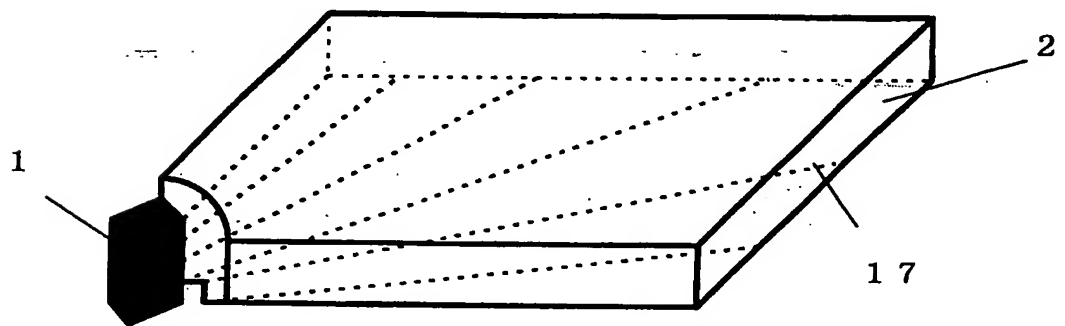
【Fig. 9】



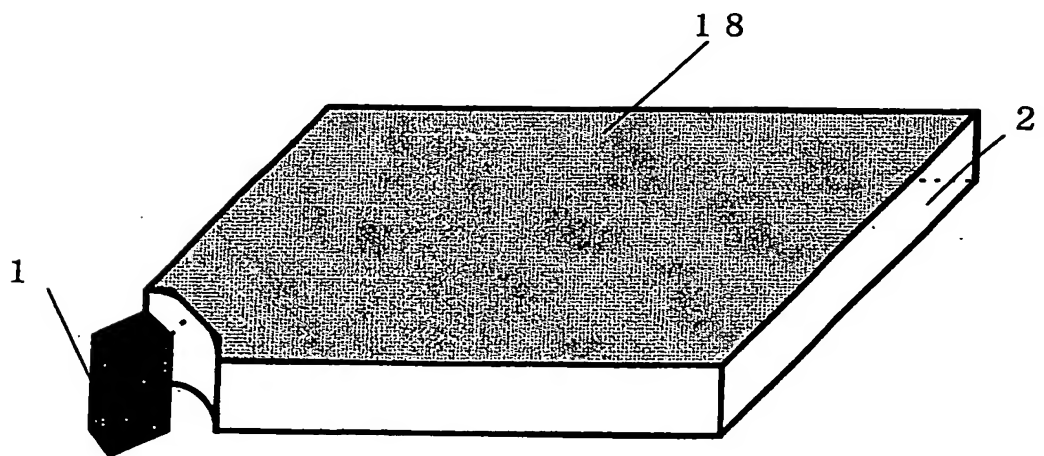
[Fig. 10]



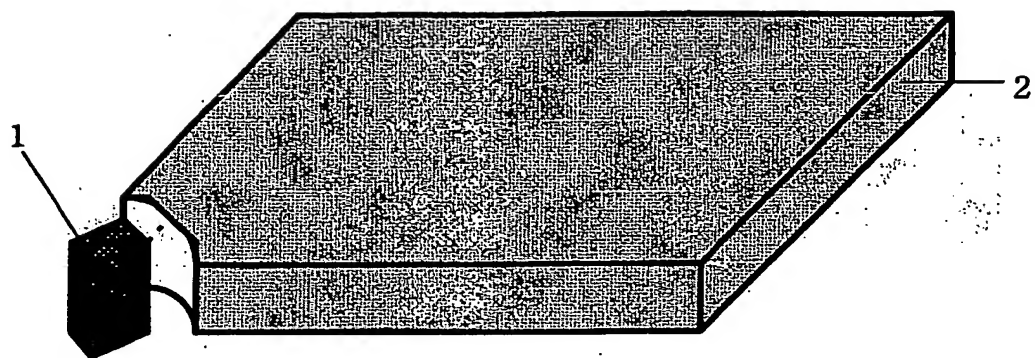
[Fig. 11]



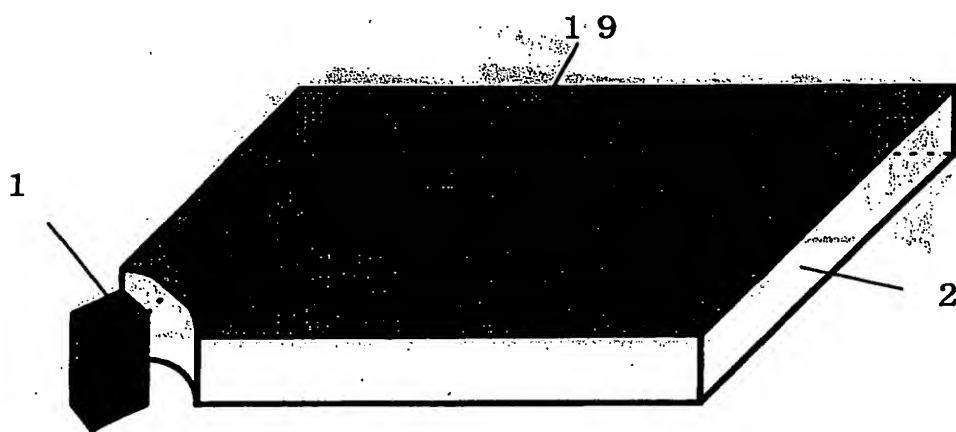
[Fig. 12]



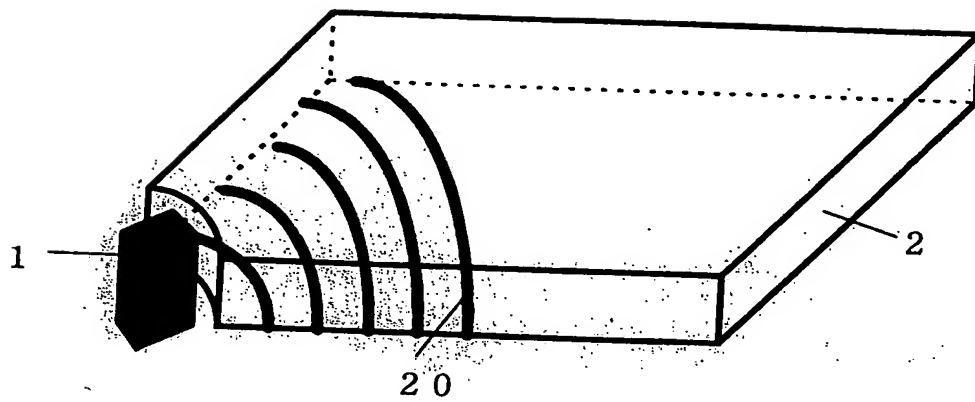
【Fig. 13】



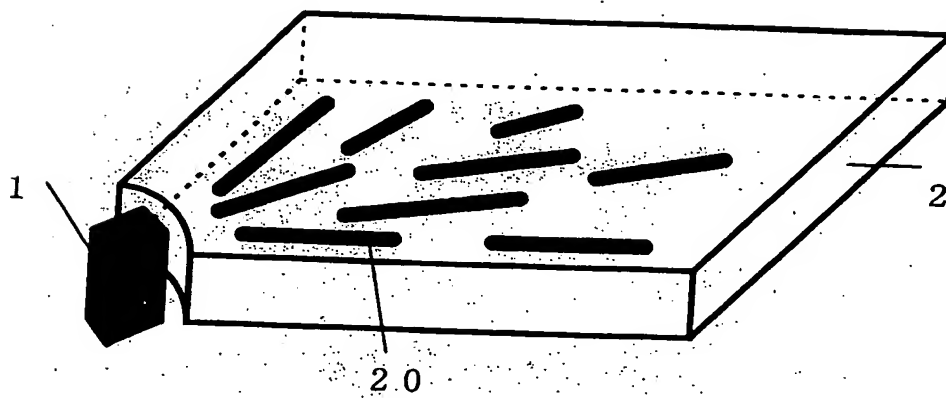
【Fig. 14】



【Fig. 15】

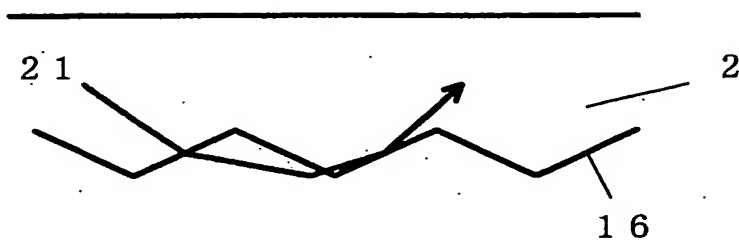


【Fig. 16】

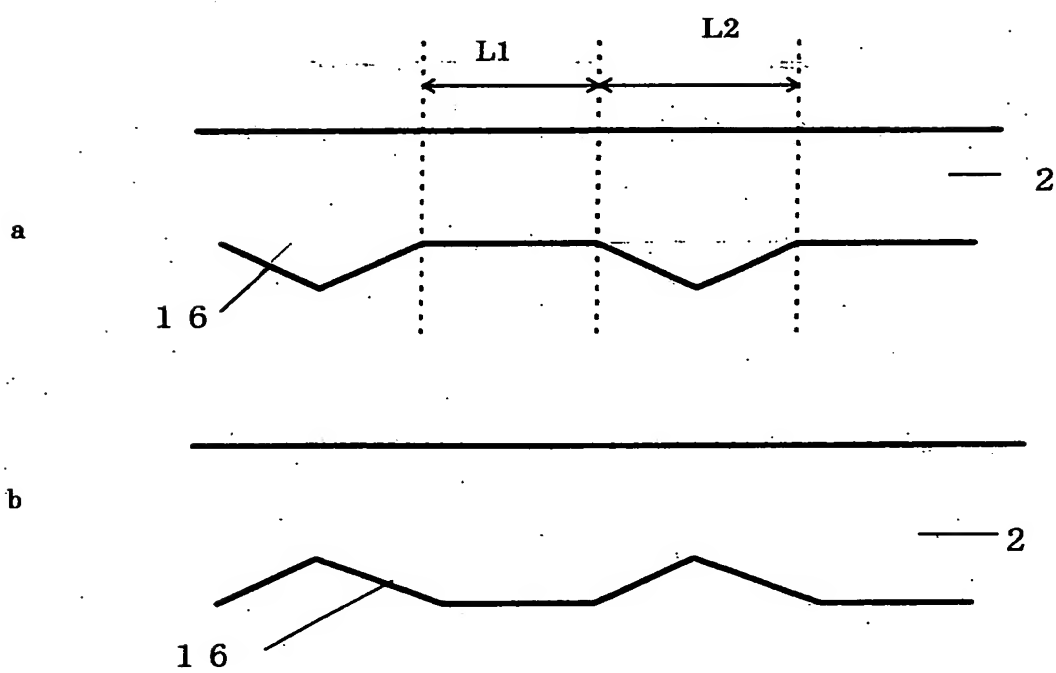




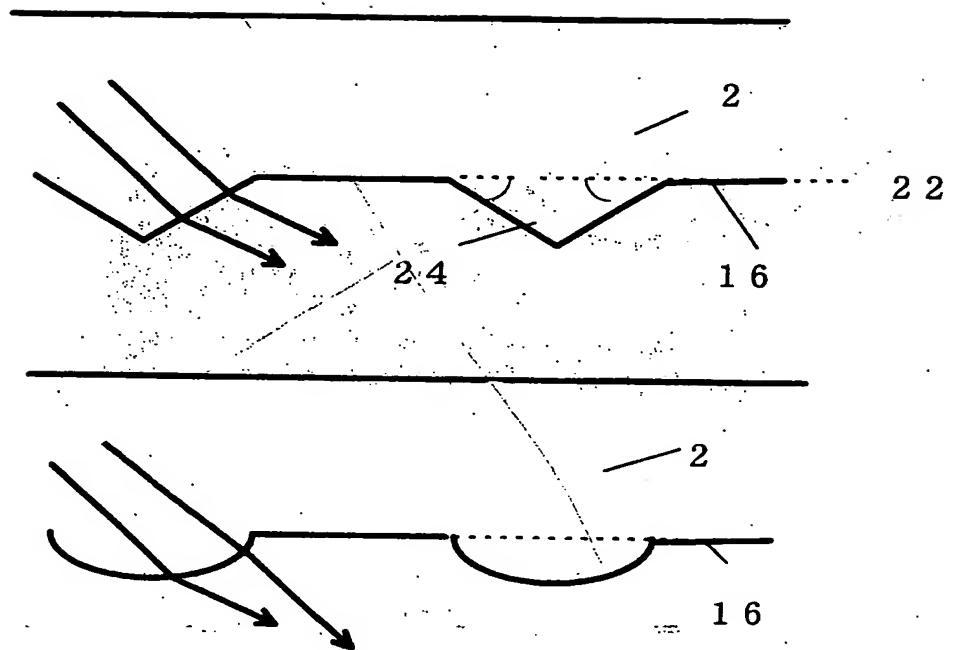
【Fig. 17】



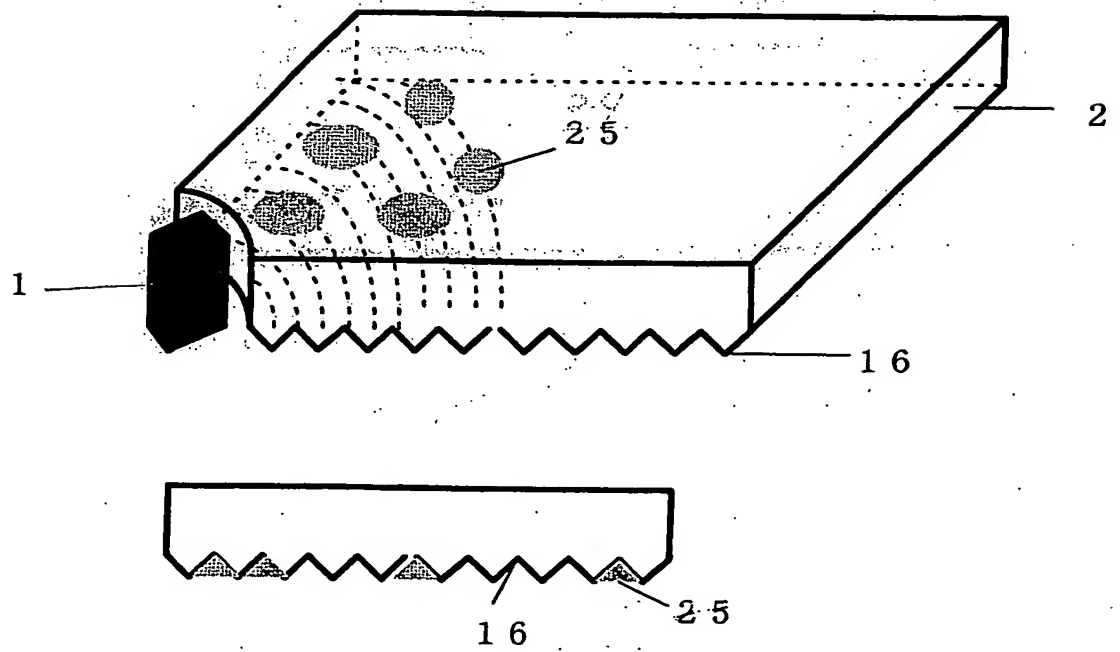
【Fig. 18】



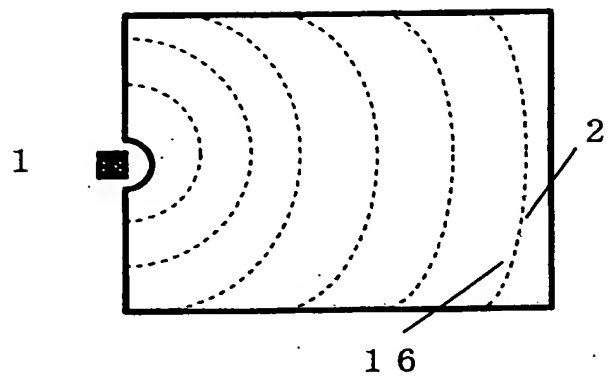
【Fig. 19】



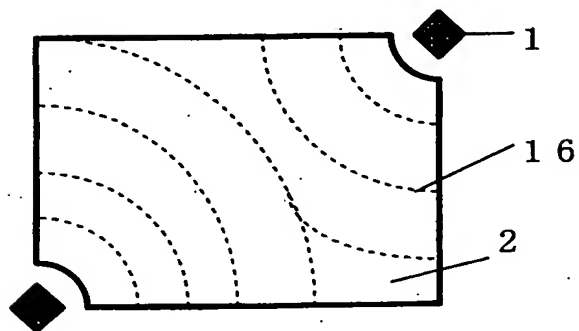
【Fig. 20】



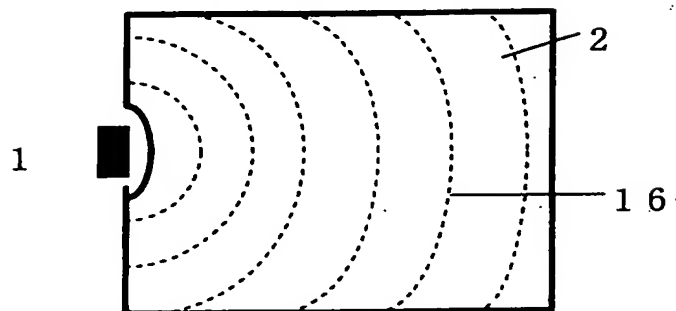
【Fig. 21】



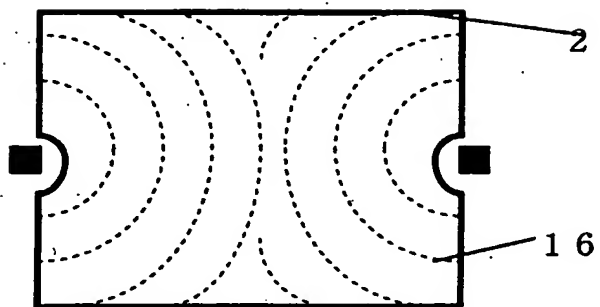
【Fig. 22】



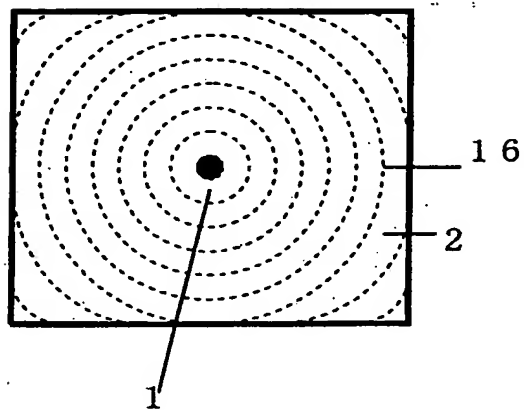
【Fig. 23】



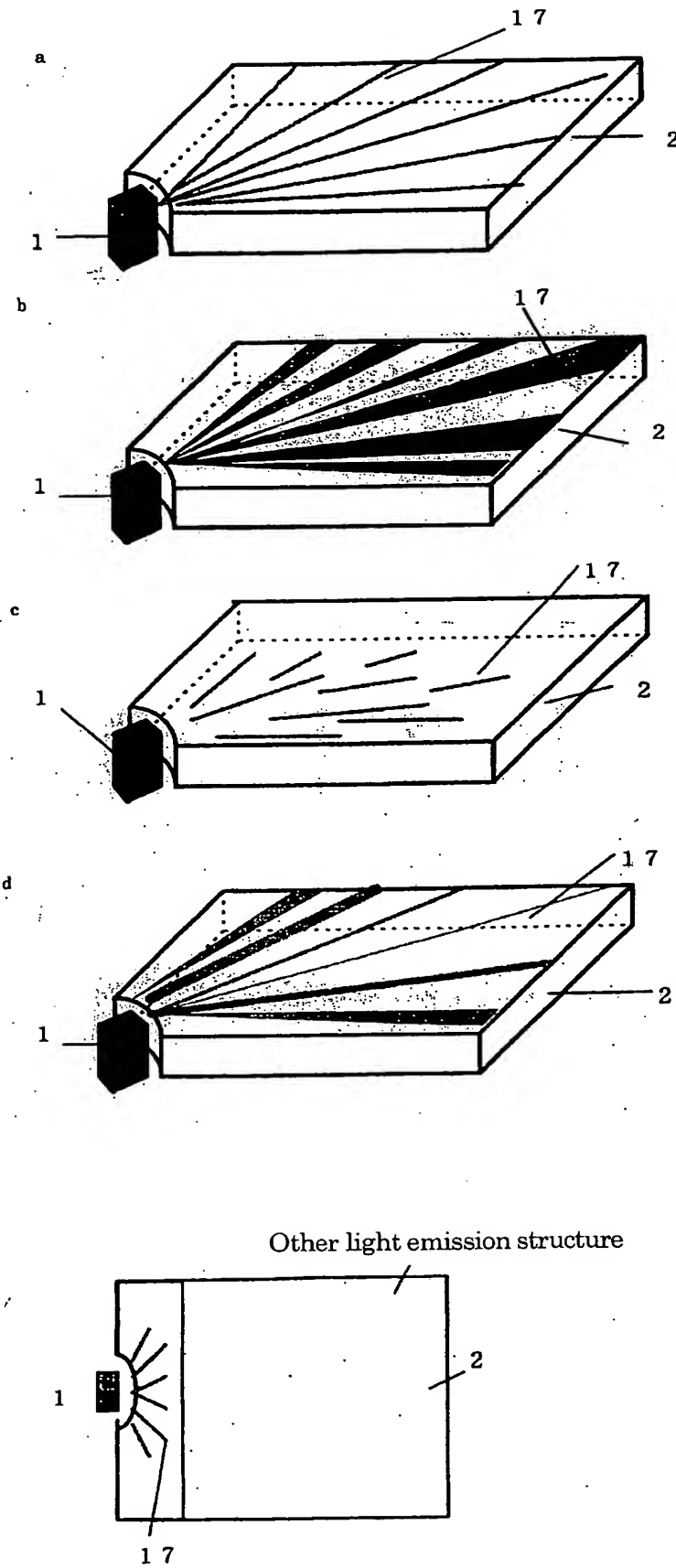
【Fig. 24】



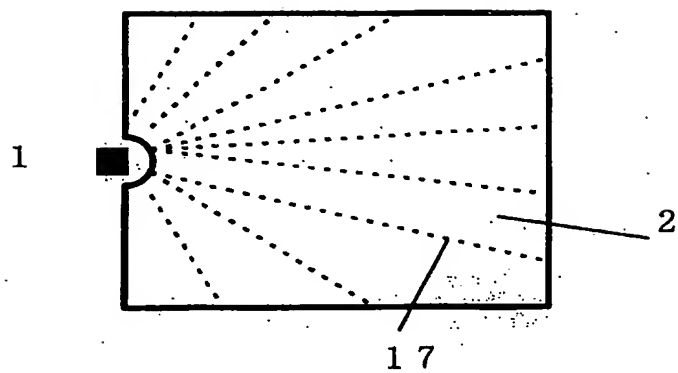
【Fig. 25】



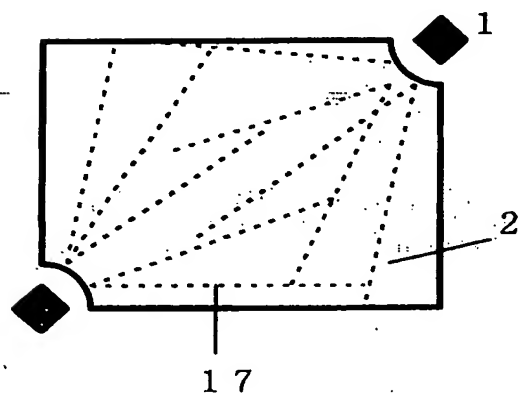
【Fig. 26】



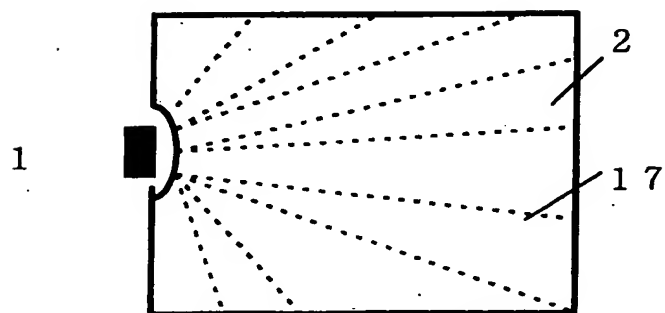
【Fig. 27】



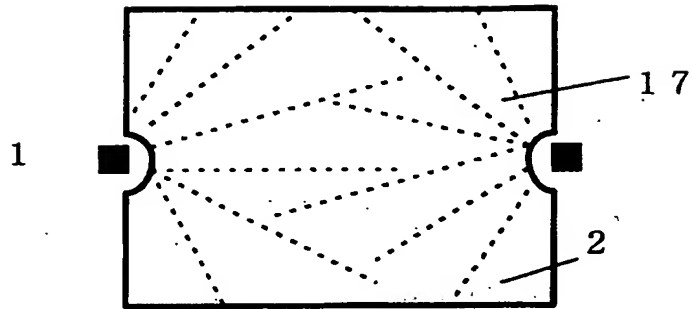
【Fig. 28】



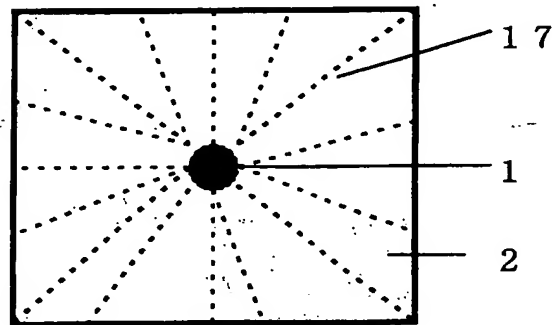
【Fig. 29】



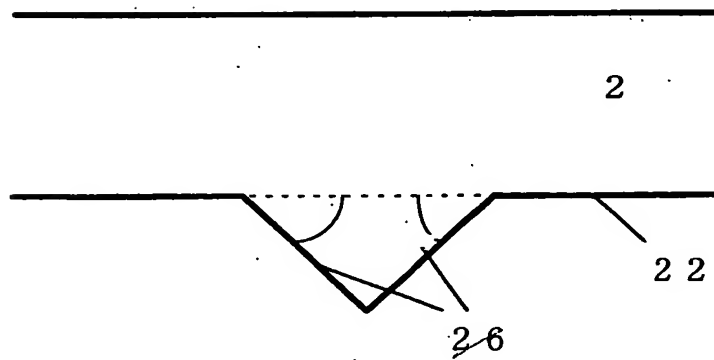
【Fig. 30】



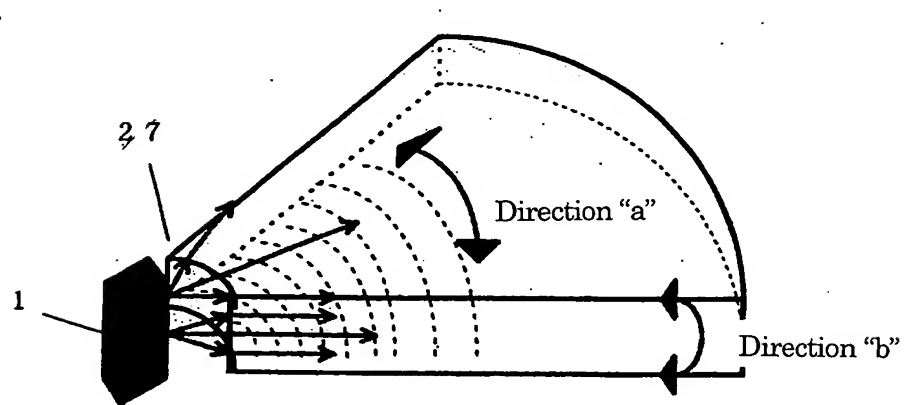
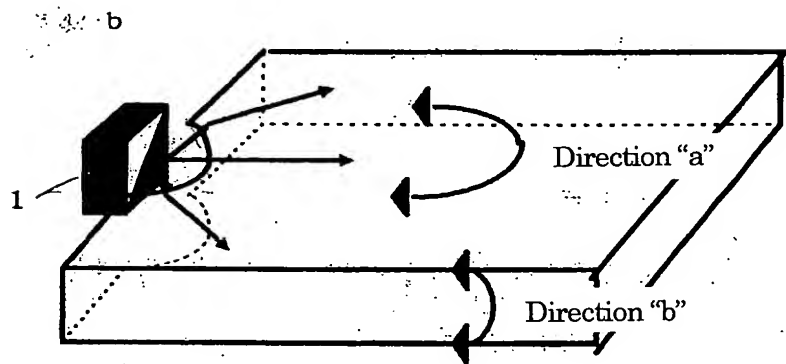
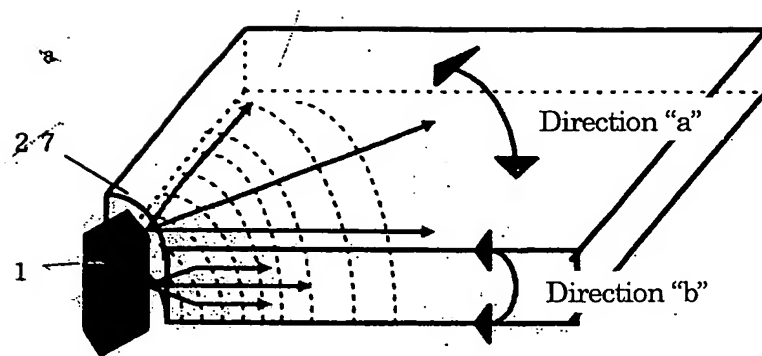
【Fig. 31】



【Fig. 32】



【Fig. 33】





**【Document Name】** ABSTRACT

**【Abstract of the Disclosure】**

**【Problem to be solved by the Invention】** To provide a planar light source device which is low in power consumption, small in thickness, high in luminance and excellent in uniformity of luminance, with use of a point-shaped light source such as an LED light source or the like.

**【Means for Solving the Problem】** A planar light source system comprising: at least one primary light source of substantially point-shape; a light guide having a light incident face on which light emitted from the primary light source is incident, guiding the incident light and having a light emission face from which the incident light is emitted; and a light deflecting device for controlling a direction of an emission light from the light guide, wherein the primary light source is disposed at a corner portion or an end surface of the light guide, and many substantially arc-shaped elongated prisms are formed in parallel to each other on at least one surface of the light deflecting device so as to surround the primary light source.

**【Representative Drawing】** Fig. 1